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(54) BEHIND-THE-METER BRANCH LOADS FOR ELECTRICAL VEHICLE CHARGING

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G05B 15/02 (2006.01)

(52) **U.S. Cl.**
CPC ***B60L 53/60*** (2019.02); ***G05B 15/02*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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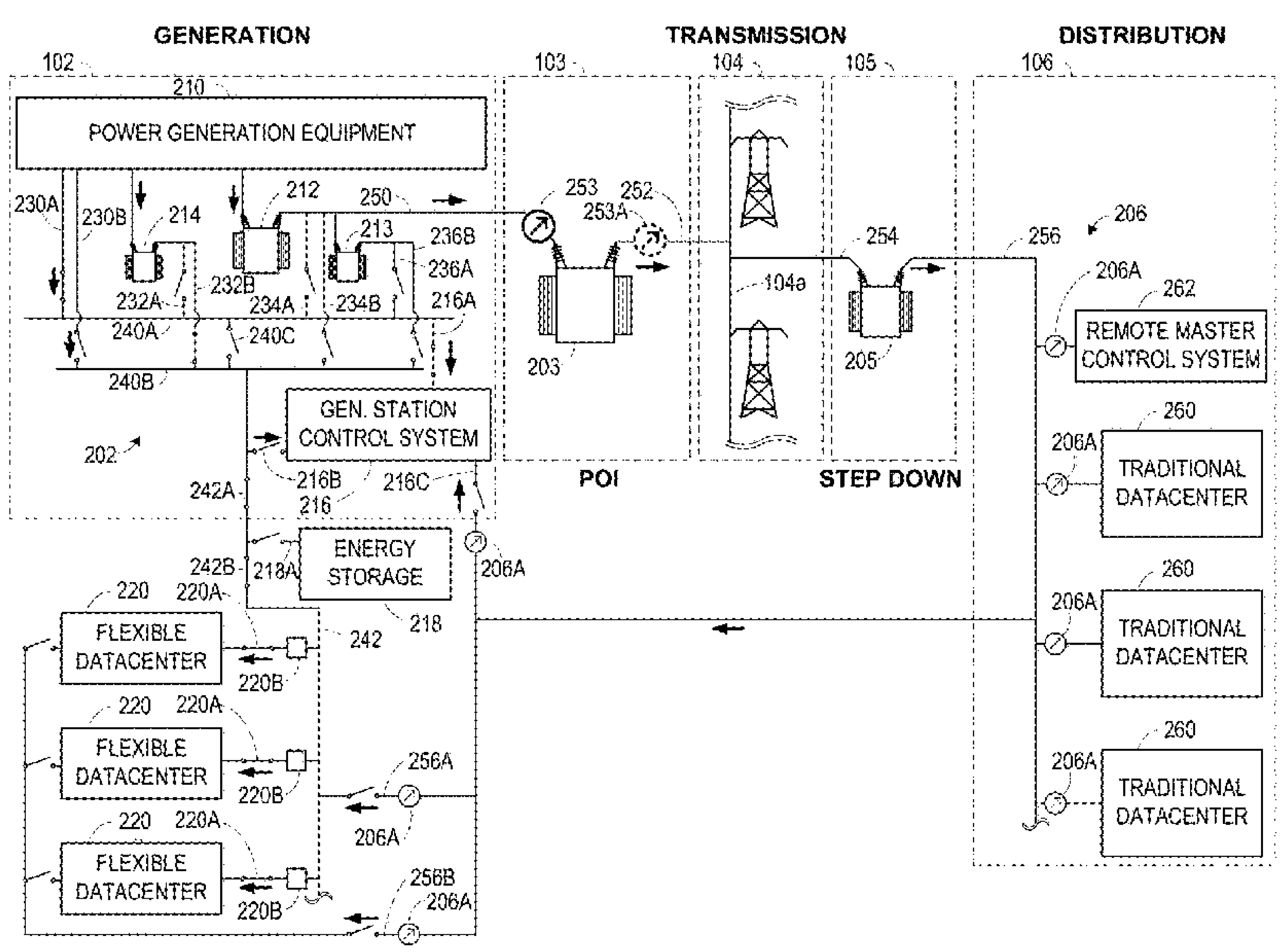
(57) **ABSTRACT**

Examples relate to flexible datacenters or other power loads tolerant of intermittent operation and configured to use power received behind-the-meter. A system may include a transportation hub electrically coupled to a BTM power source via a branch line. The transportation hub may receive behind-the-meter ("BTM") power from the BTM power source. The system may also include a datacenter control system configured to modulate power delivery to the transportation hub based on a set of monitored conditions. The set of monitored conditions may include BTM power availability at the transportation hub. In some examples, the datacenter control system is a remote master control system positioned remotely from the transportation hub.

26 Claims, 15 Drawing Sheets



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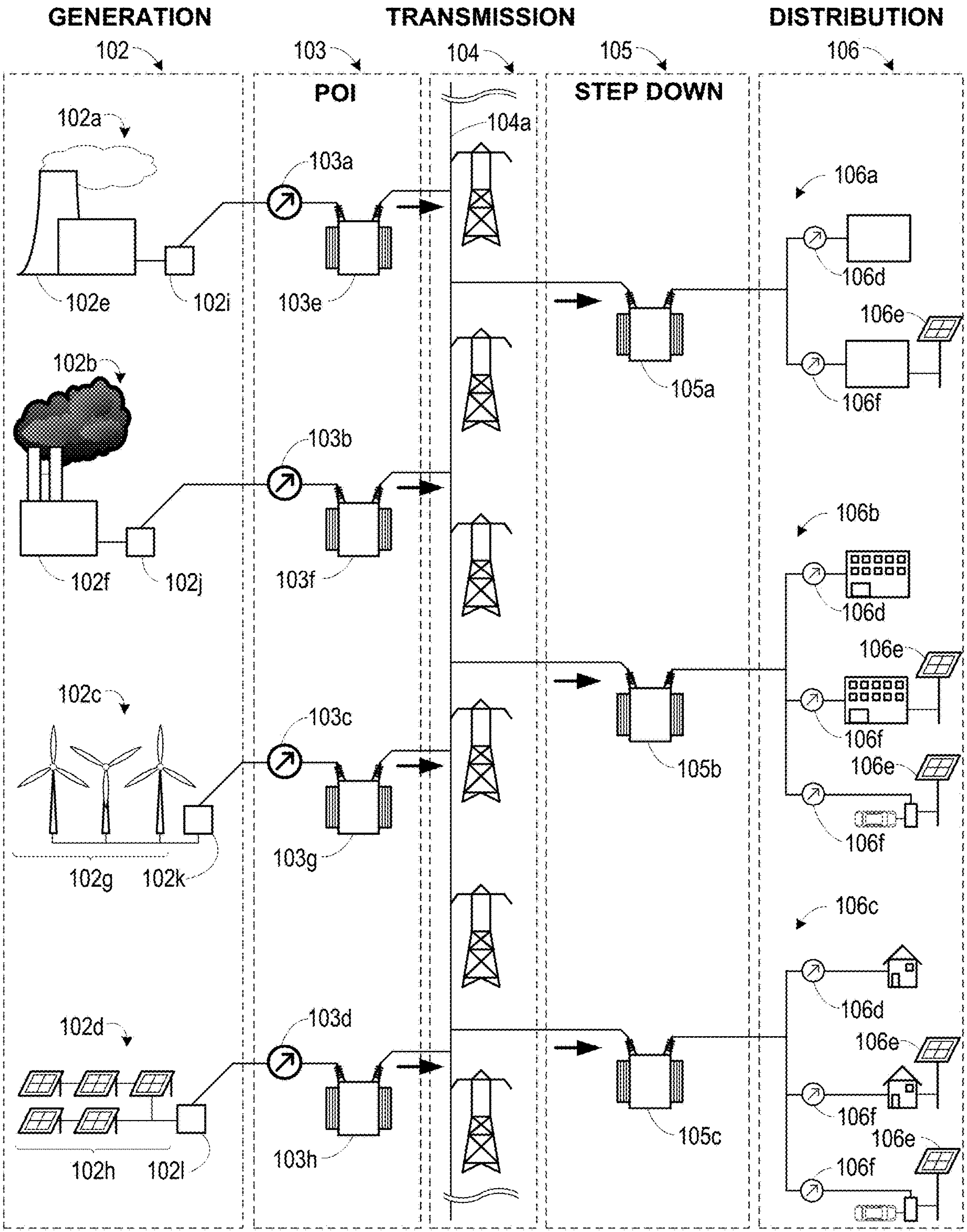

PRIOR ART
FIGURE 1

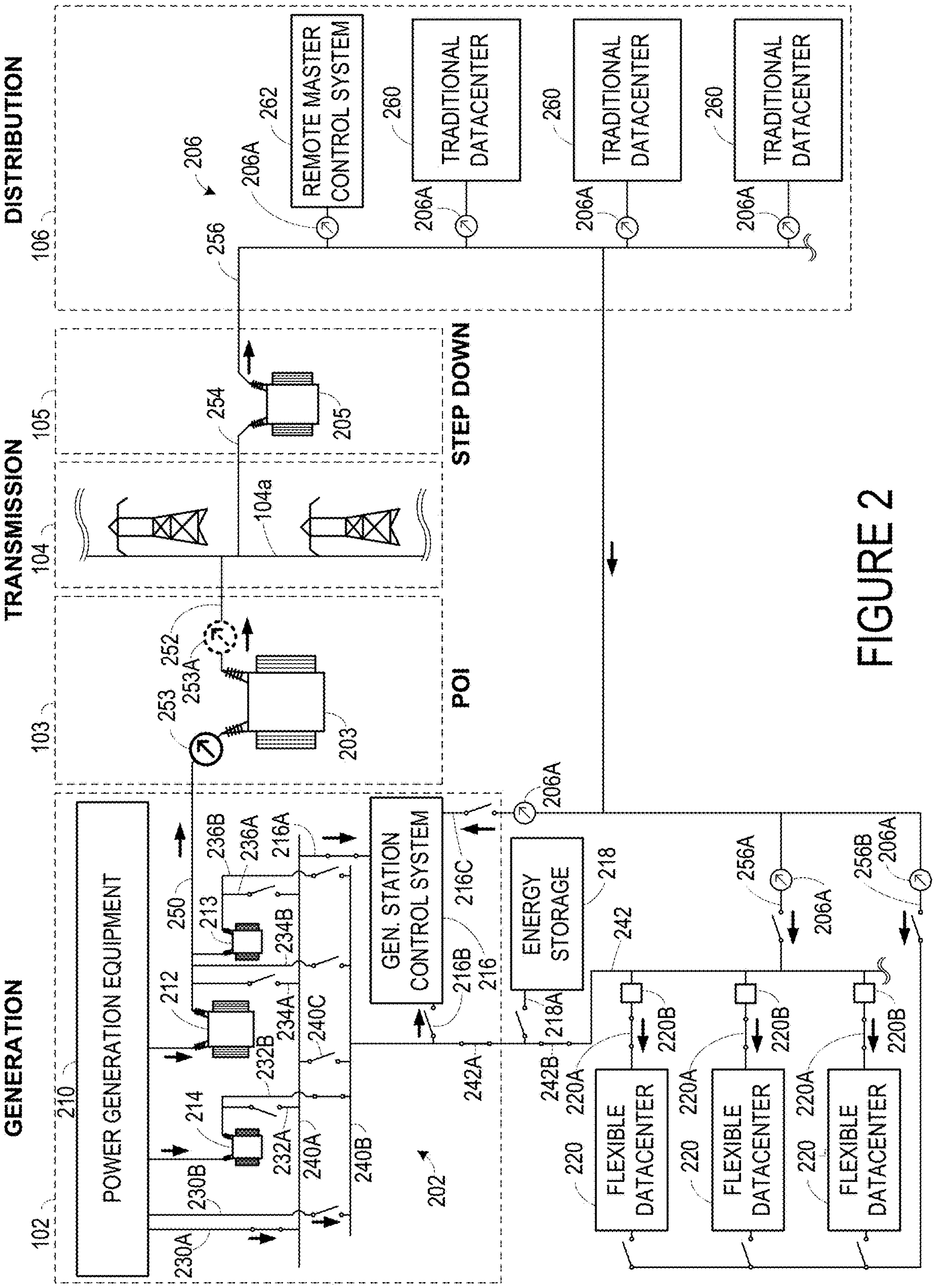
GENERATION
102
POWER GENERATION EQUIPMENT
210
230A
230B
214
212
213
232A
232B
234A
234B
236A
236B
240A
240B
240C
250
216A
216B
216C
216
GEN. STATION CONTROL SYSTEM
242A
242B
218A
ENERGY STORAGE
218
242
202
FLEXIBLE DATACENTER
220
220A
220B
256A
256B
206A
TRANSMISSION
103
POI
253
253A
252
203
104
104a
105
STEP DOWN
254
205
DISTRIBUTION
106
256
206
REMOTE MASTER CONTROL SYSTEM
262
TRADITIONAL DATACENTER
260

FIGURE 2

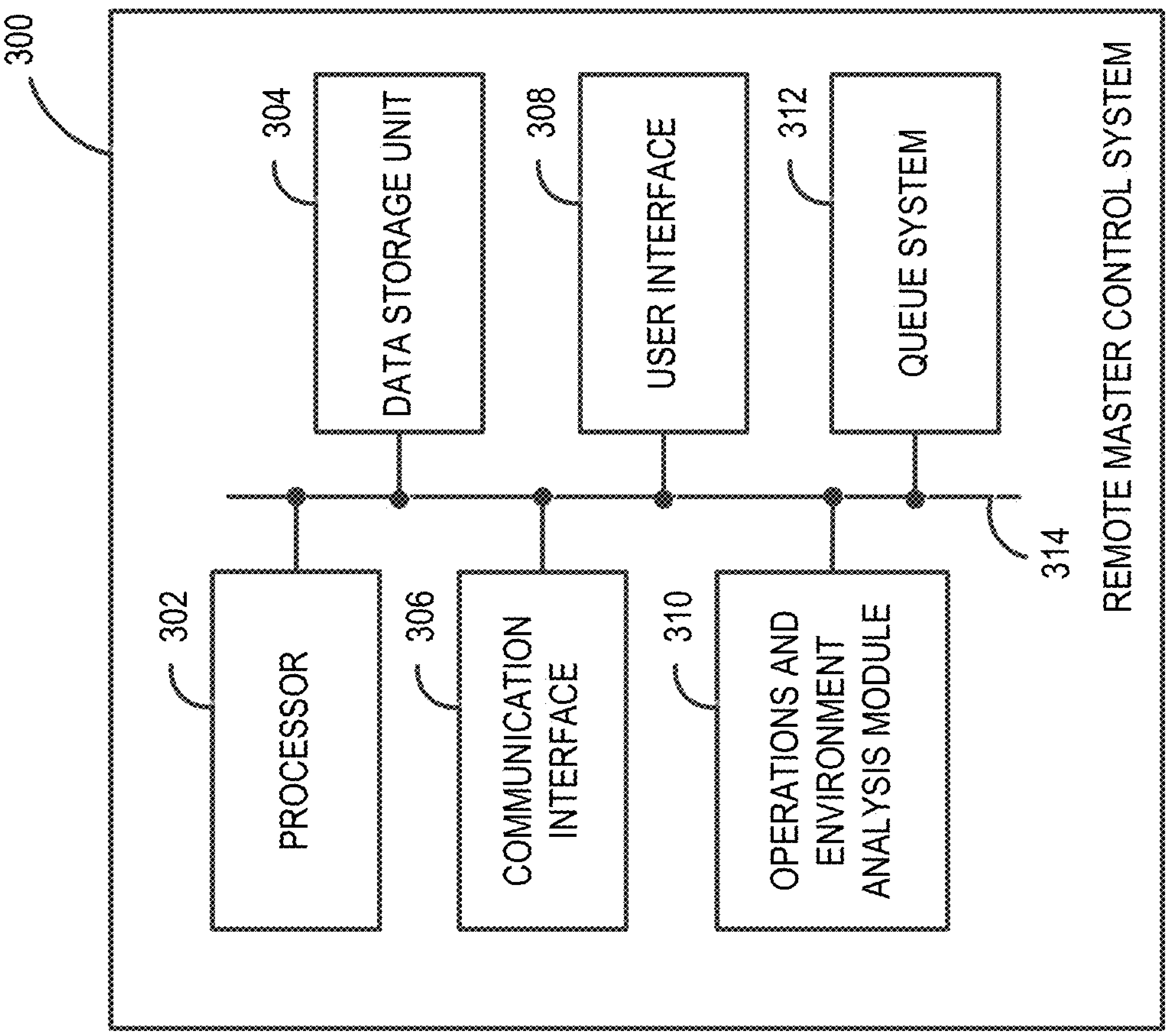
300
302
PROCESSOR
304
DATA STORAGE UNIT
306
COMMUNICATION INTERFACE
308
USER INTERFACE
310
OPERATIONS AND ENVIRONMENT ANALYSIS MODULE
312
QUEUE SYSTEM
314
REMOTE MASTER CONTROL SYSTEM

FIGURE 3

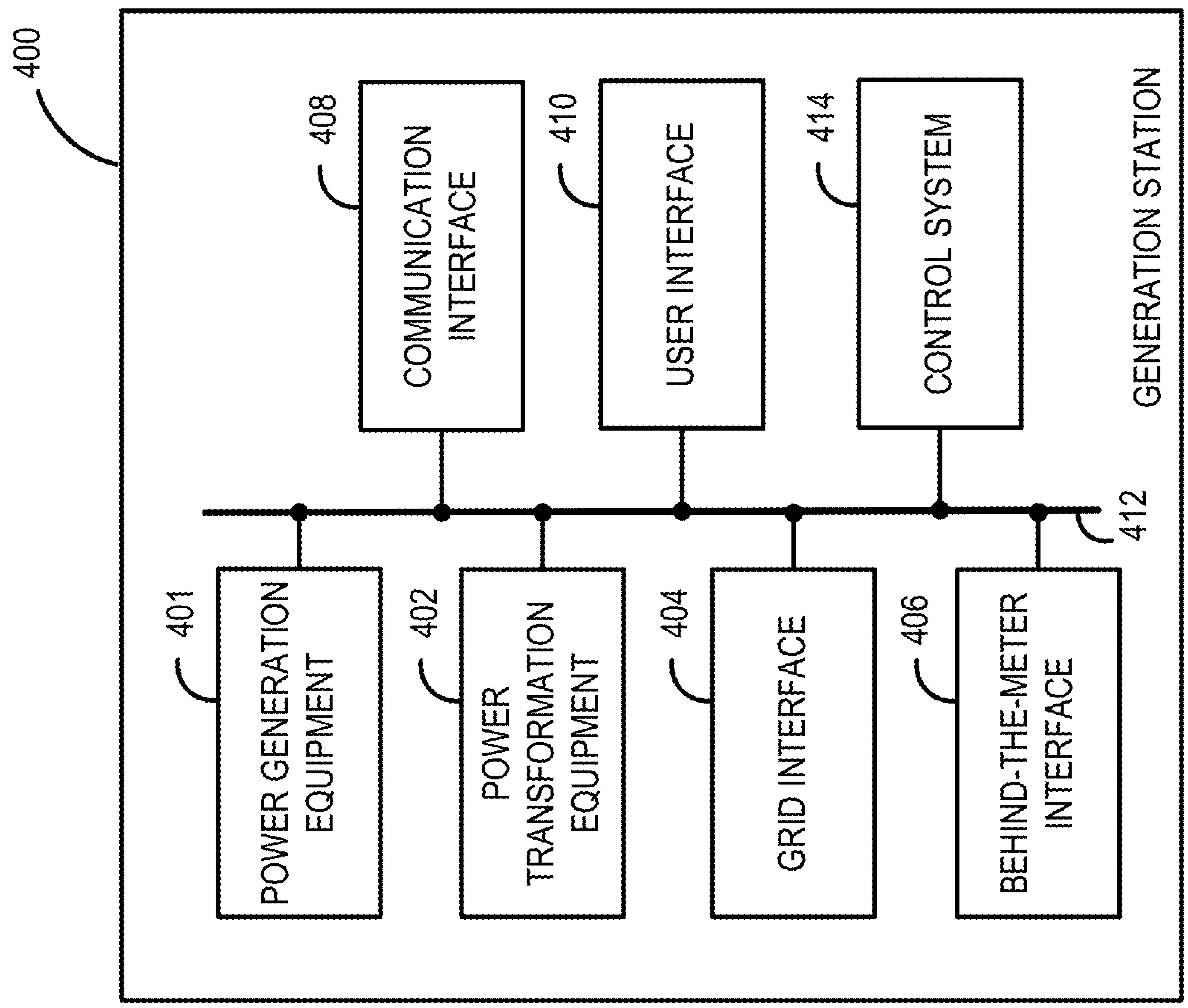
400
408
COMMUNICATION INTERFACE
410
USER INTERFACE
414
CONTROL SYSTEM
GENERATION STATION
412
401
POWER GENERATION EQUIPMENT
402
POWER TRANSFORMATION EQUIPMENT
404
GRID INTERFACE
406
BEHIND-THE-METER INTERFACE

FIGURE 4

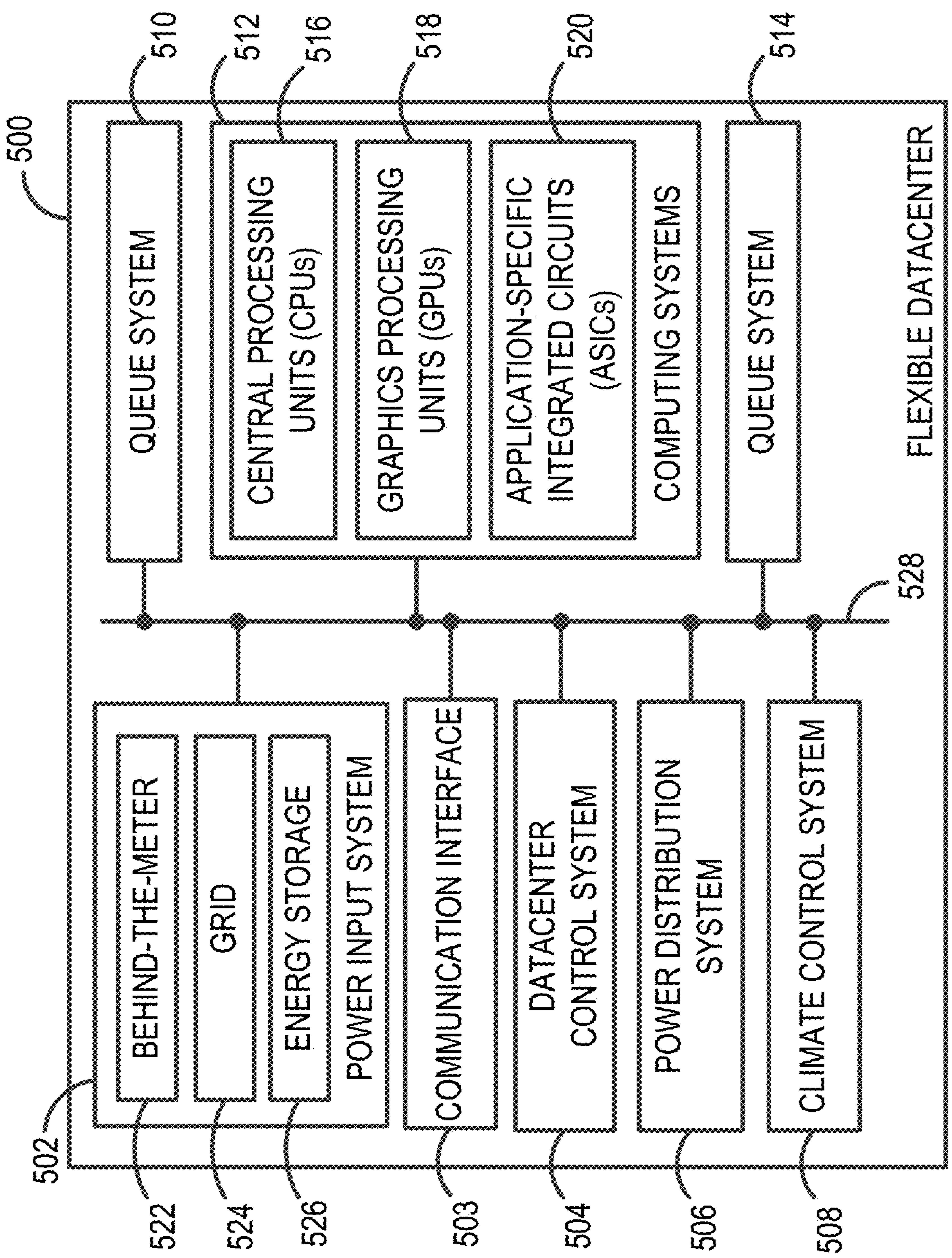
500
502
QUEUE SYSTEM
510
CENTRAL PROCESSING UNITS (CPUs)
516
GRAPHICS PROCESSING UNITS (GPUs)
518
APPLICATION-SPECIFIC INTEGRATED CIRCUITS (ASICs)
520
COMPUTING SYSTEMS
512
QUEUE SYSTEM
514
FLEXIBLE DATACENTER
528
BEHIND-THE-METER
522
GRID
524
ENERGY STORAGE
526
POWER INPUT SYSTEM
COMMUNICATION INTERFACE
503
DATACENTER CONTROL SYSTEM
504
POWER DISTRIBUTION SYSTEM
506
CLIMATE CONTROL SYSTEM
508

FIGURE 5

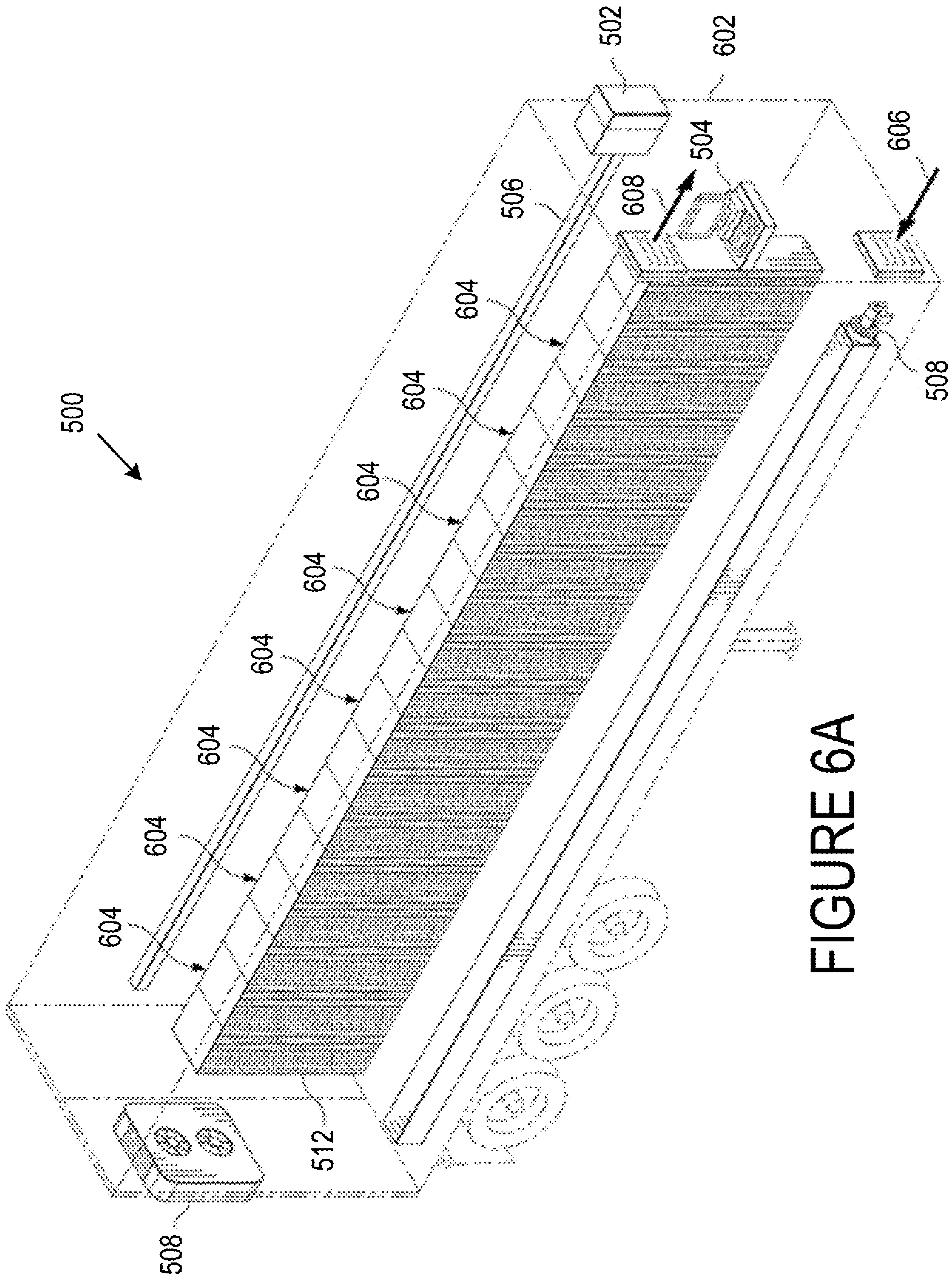
500
502
602
504
506
608
606
604
604
604
604
604
604
604
604
508
512
508

FIGURE 6A

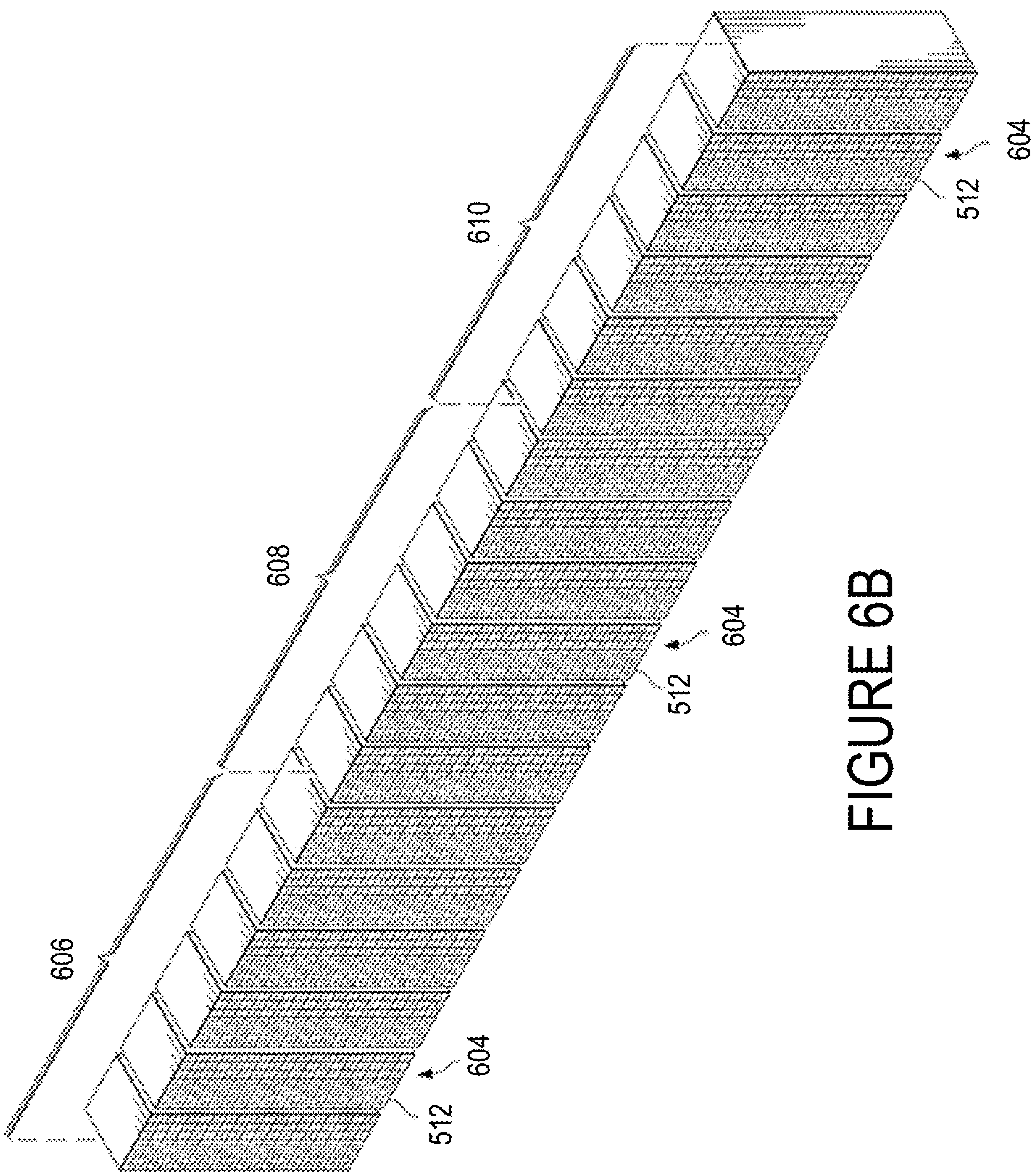

FIGURE 6B

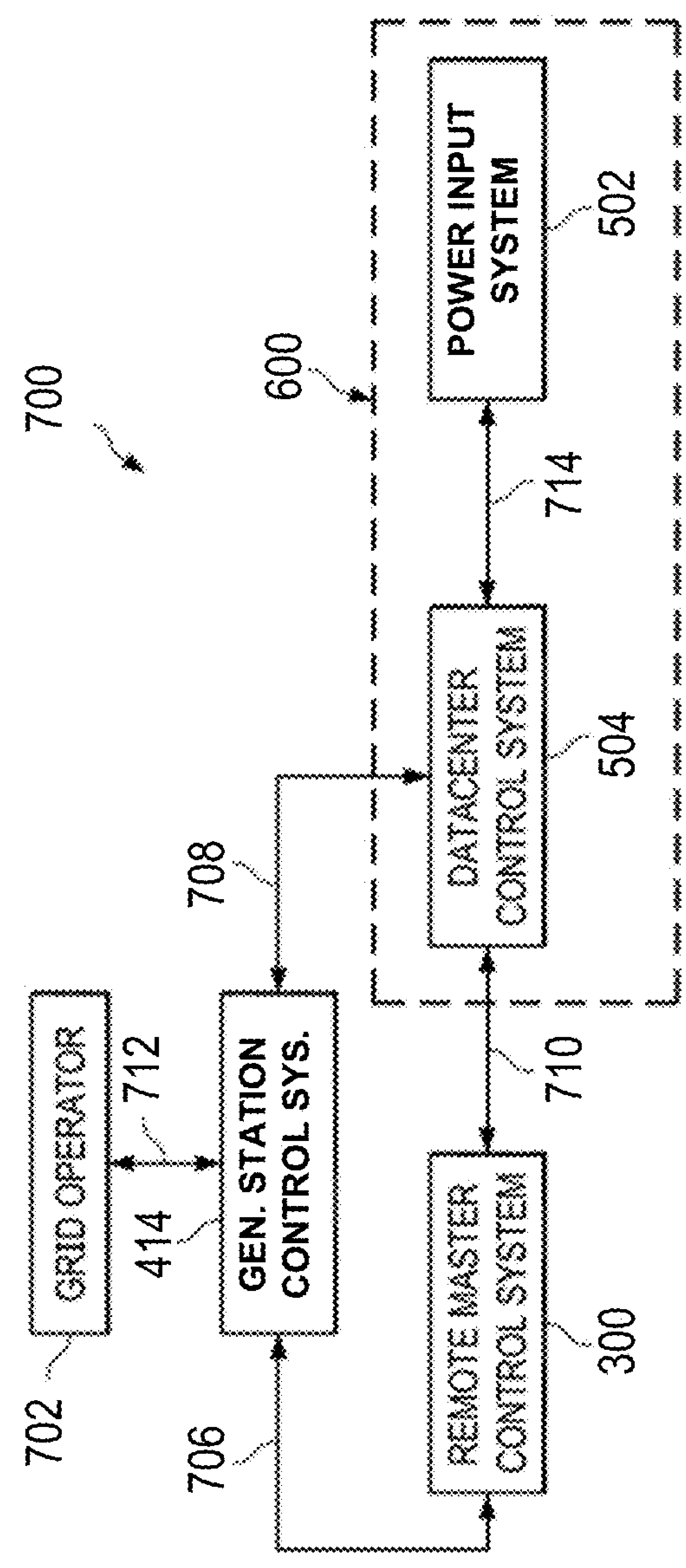
700
600
POWER INPUT SYSTEM
502
714
DATACENTER CONTROL SYSTEM
504
708
GRID OPERATOR
712
GEN. STATION CONTROL SYS.
414
710
REMOTE MASTER CONTROL SYSTEM
300
702
706

FIGURE 7

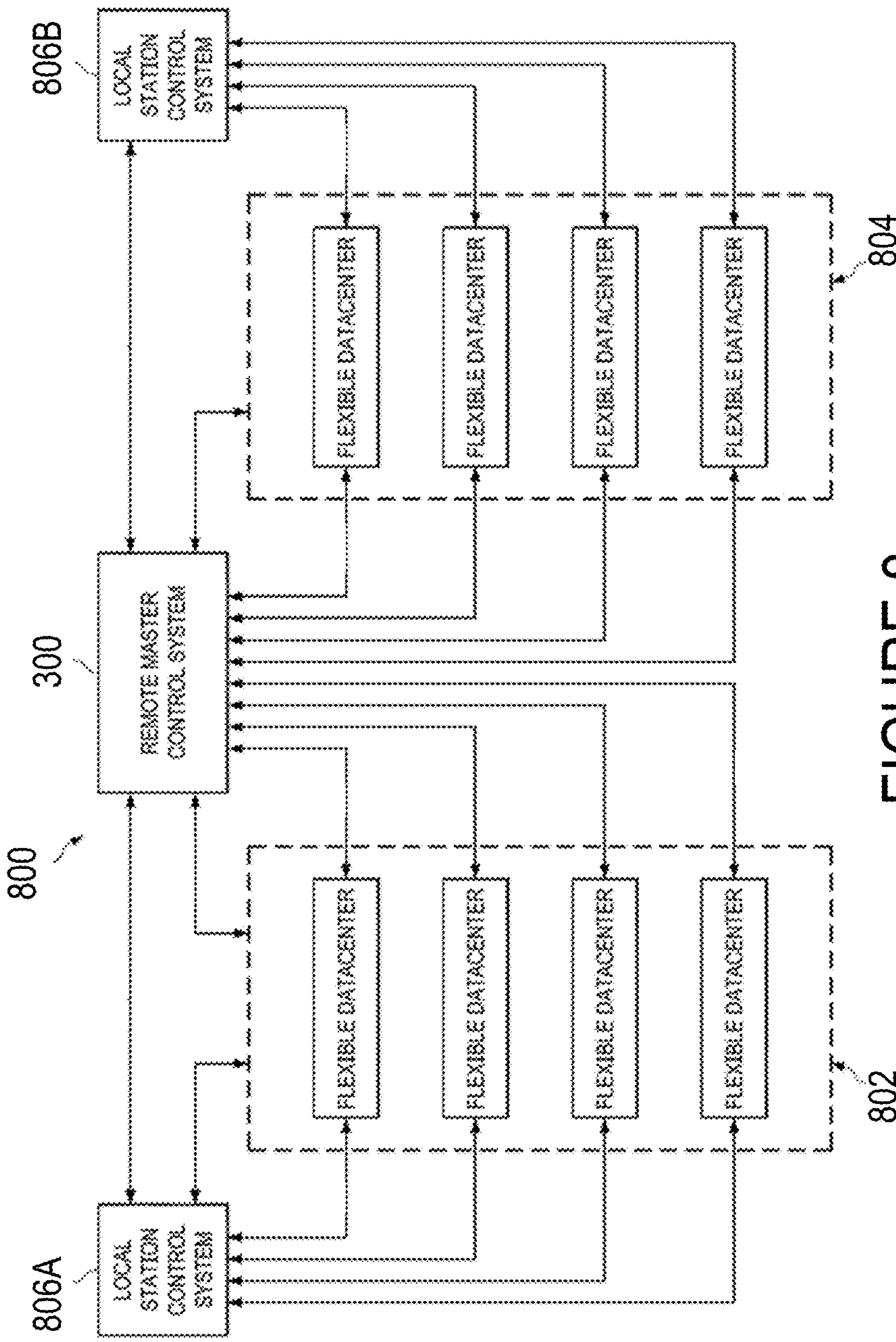
800
300
REMOTE MASTER CONTROL SYSTEM
806A
LOCAL STATION CONTROL SYSTEM
806B
LOCAL STATION CONTROL SYSTEM
802
FLEXIBLE DATACENTER
FLEXIBLE DATACENTER
FLEXIBLE DATACENTER
FLEXIBLE DATACENTER
804
FLEXIBLE DATACENTER
FLEXIBLE DATACENTER
FLEXIBLE DATACENTER
FLEXIBLE DATACENTER

FIGURE 8

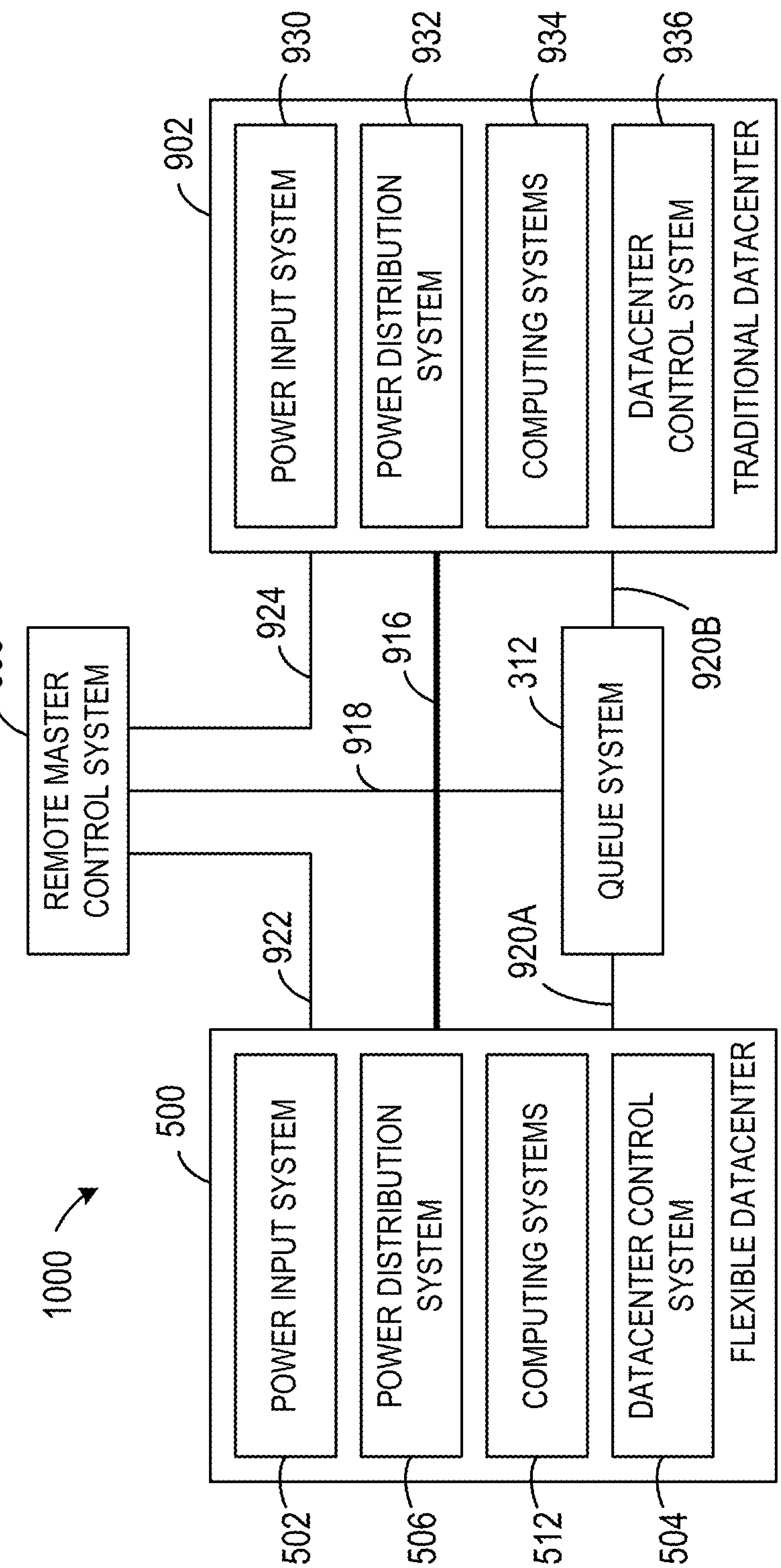
1000
500
POWER INPUT SYSTEM
POWER DISTRIBUTION SYSTEM
COMPUTING SYSTEMS
DATACENTER CONTROL SYSTEM
FLEXIBLE DATACENTER
502
506
512
504
922
920A
300
REMOTE MASTER CONTROL SYSTEM
918
916
924
312
QUEUE SYSTEM
920B
902
POWER INPUT SYSTEM
POWER DISTRIBUTION SYSTEM
COMPUTING SYSTEMS
DATACENTER CONTROL SYSTEM
TRADITIONAL DATACENTER
930
932
934
936

FIGURE 9

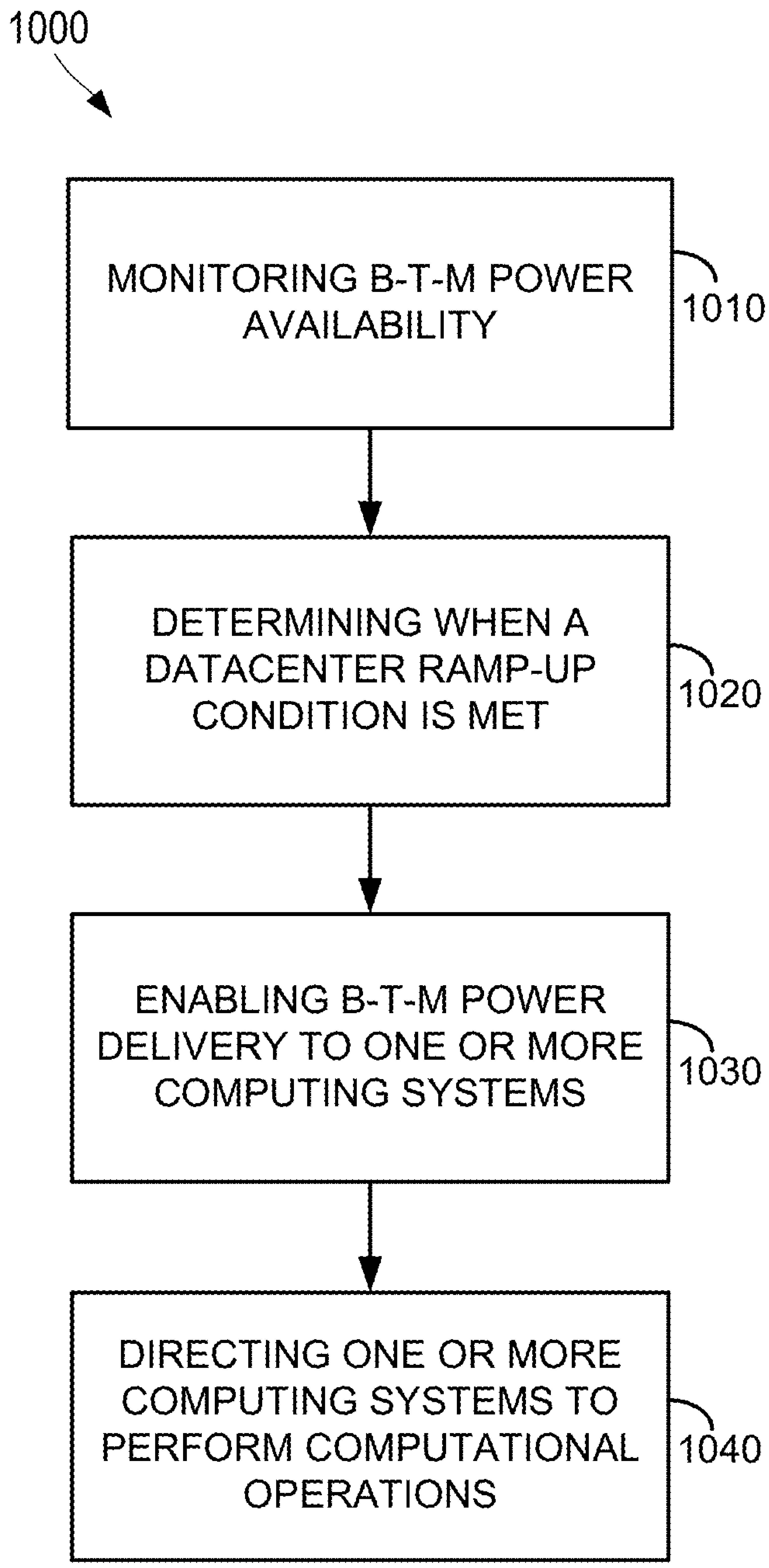
1000
MONITORING B-T-M POWER AVAILABILITY
1010
DETERMINING WHEN A DATACENTER RAMP-UP CONDITION IS MET
1020
ENABLING B-T-M POWER DELIVERY TO ONE OR MORE COMPUTING SYSTEMS
1030
DIRECTING ONE OR MORE COMPUTING SYSTEMS TO PERFORM COMPUTATIONAL OPERATIONS
1040

FIGURE 10A

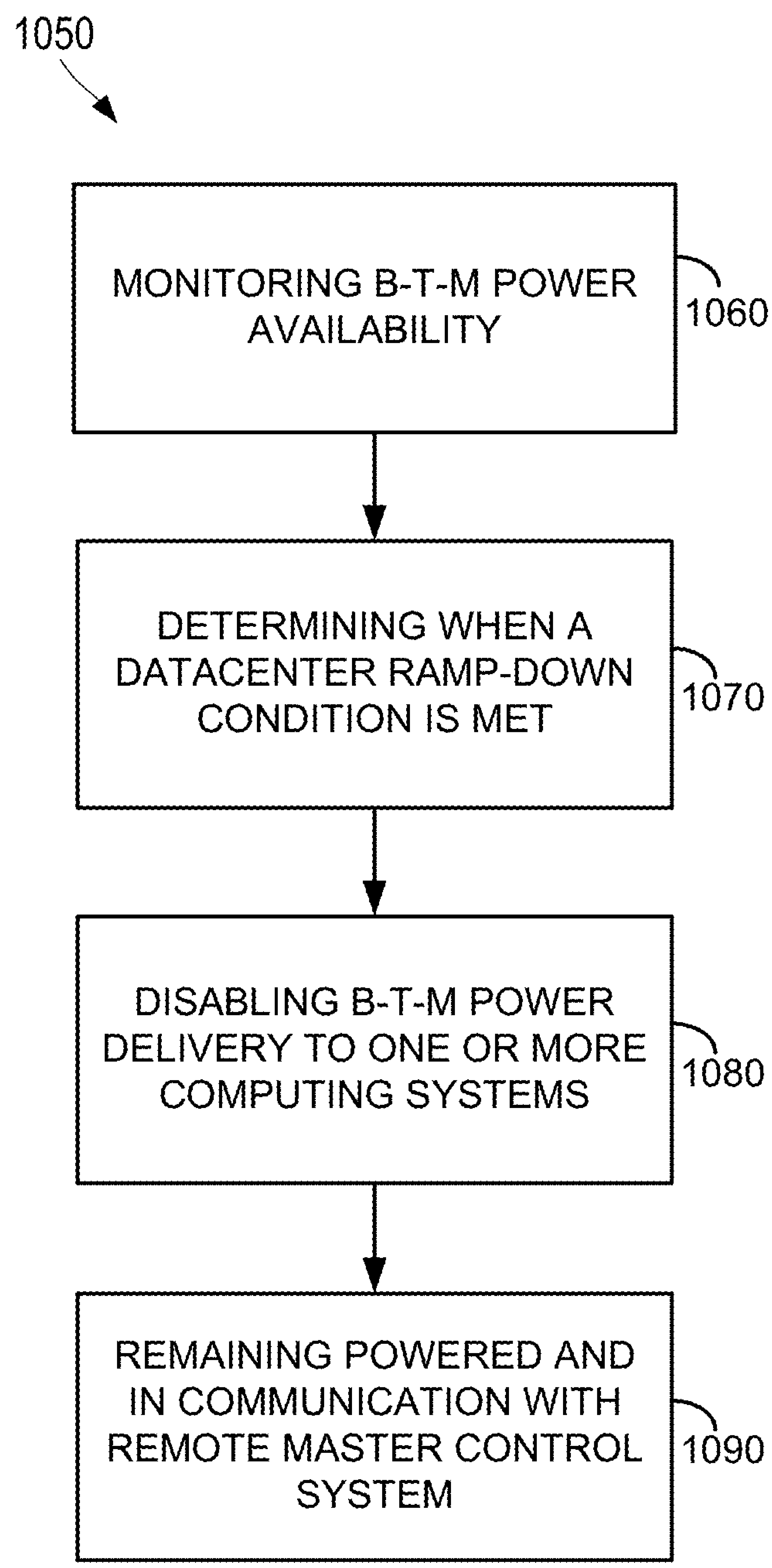
1050
MONITORING B-T-M POWER AVAILABILITY
1060
DETERMINING WHEN A DATACENTER RAMP-DOWN CONDITION IS MET
1070
DISABLING B-T-M POWER DELIVERY TO ONE OR MORE COMPUTING SYSTEMS
1080
REMAINING POWERED AND IN COMMUNICATION WITH REMOTE MASTER CONTROL SYSTEM
1090

FIGURE 10B

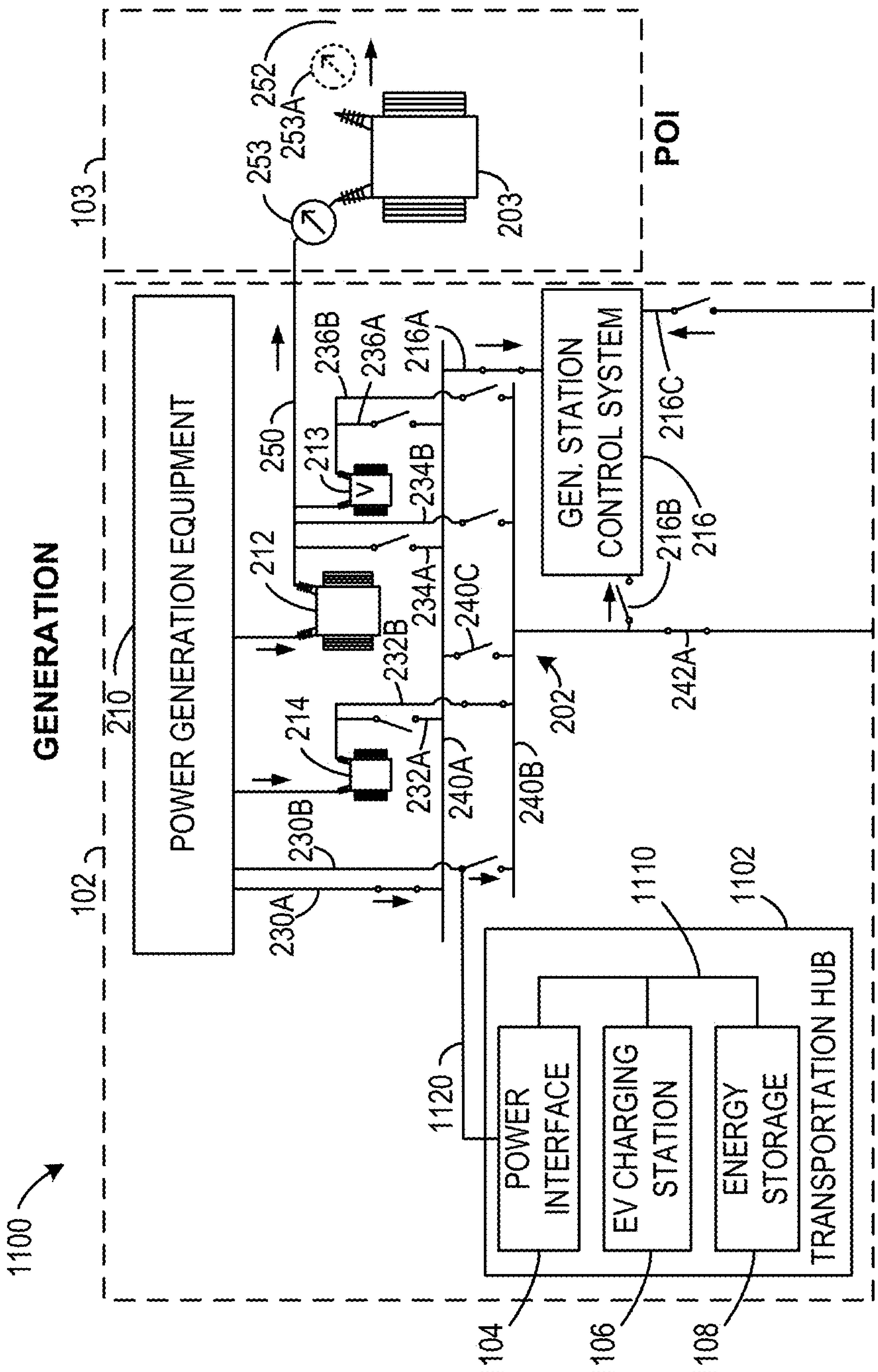
1100
GENERATION
102
210
POWER GENERATION EQUIPMENT
230A
230B
214
212
213
V
250
236B
236A
216A
232A
232B
234A
234B
240A
240B
240C
202
242A
GEN. STATION CONTROL SYSTEM
216B
216
216C
103
253
253A
252
203
POI
1120
1110
1102
POWER INTERFACE
EV CHARGING STATION
ENERGY STORAGE
TRANSPORTATION HUB
1104
1106
1108

FIGURE 11

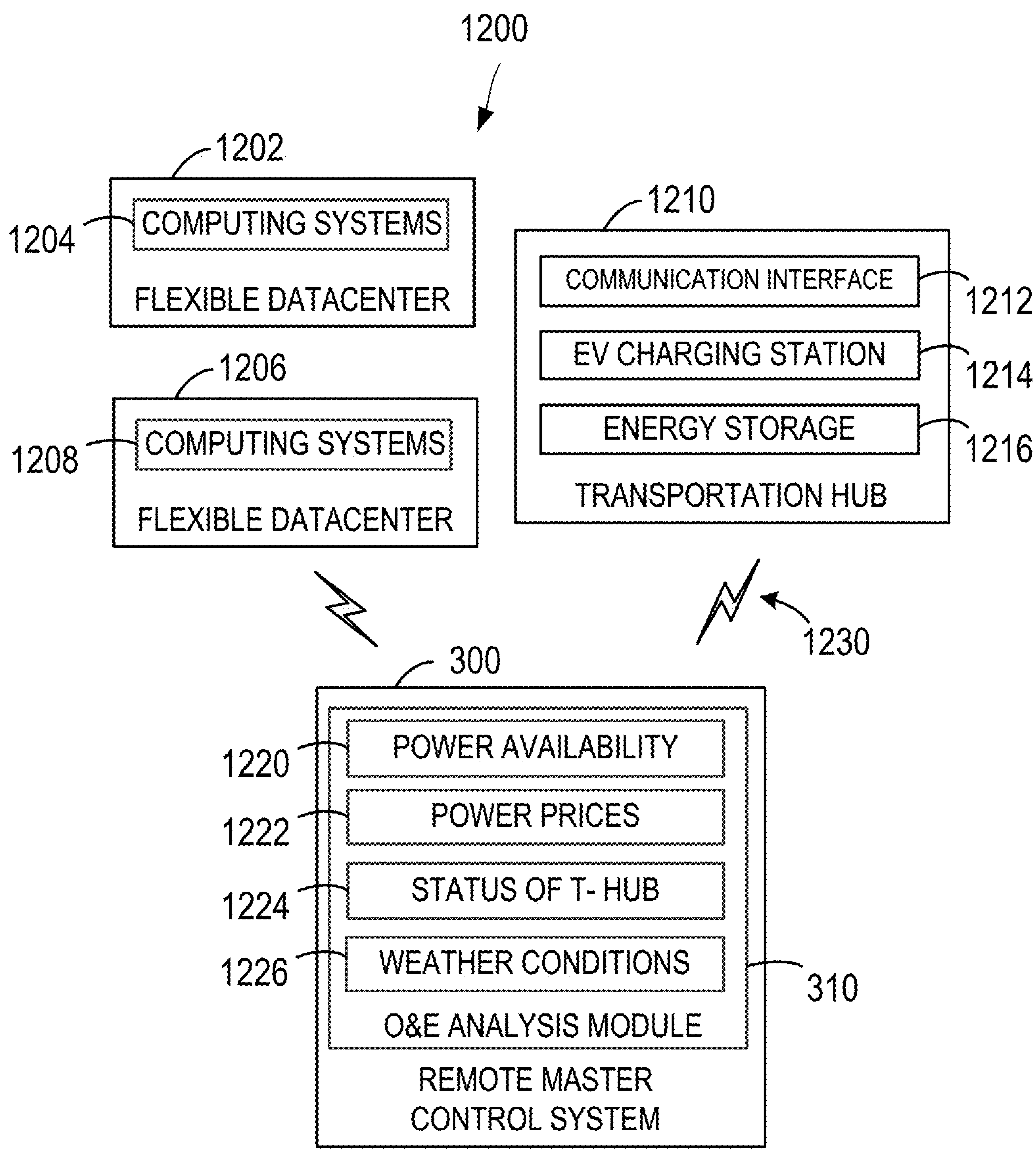
1200
1202
1204
COMPUTING SYSTEMS
FLEXIBLE DATACENTER
1206
1208
COMPUTING SYSTEMS
FLEXIBLE DATACENTER
1210
COMMUNICATION INTERFACE
1212
EV CHARGING STATION
1214
ENERGY STORAGE
1216
TRANSPORTATION HUB
1230
300
1220
POWER AVAILABILITY
1222
POWER PRICES
1224
STATUS OF T- HUB
1226
WEATHER CONDITIONS
310
O&E ANALYSIS MODULE
REMOTE MASTER
CONTROL SYSTEM

FIGURE 12

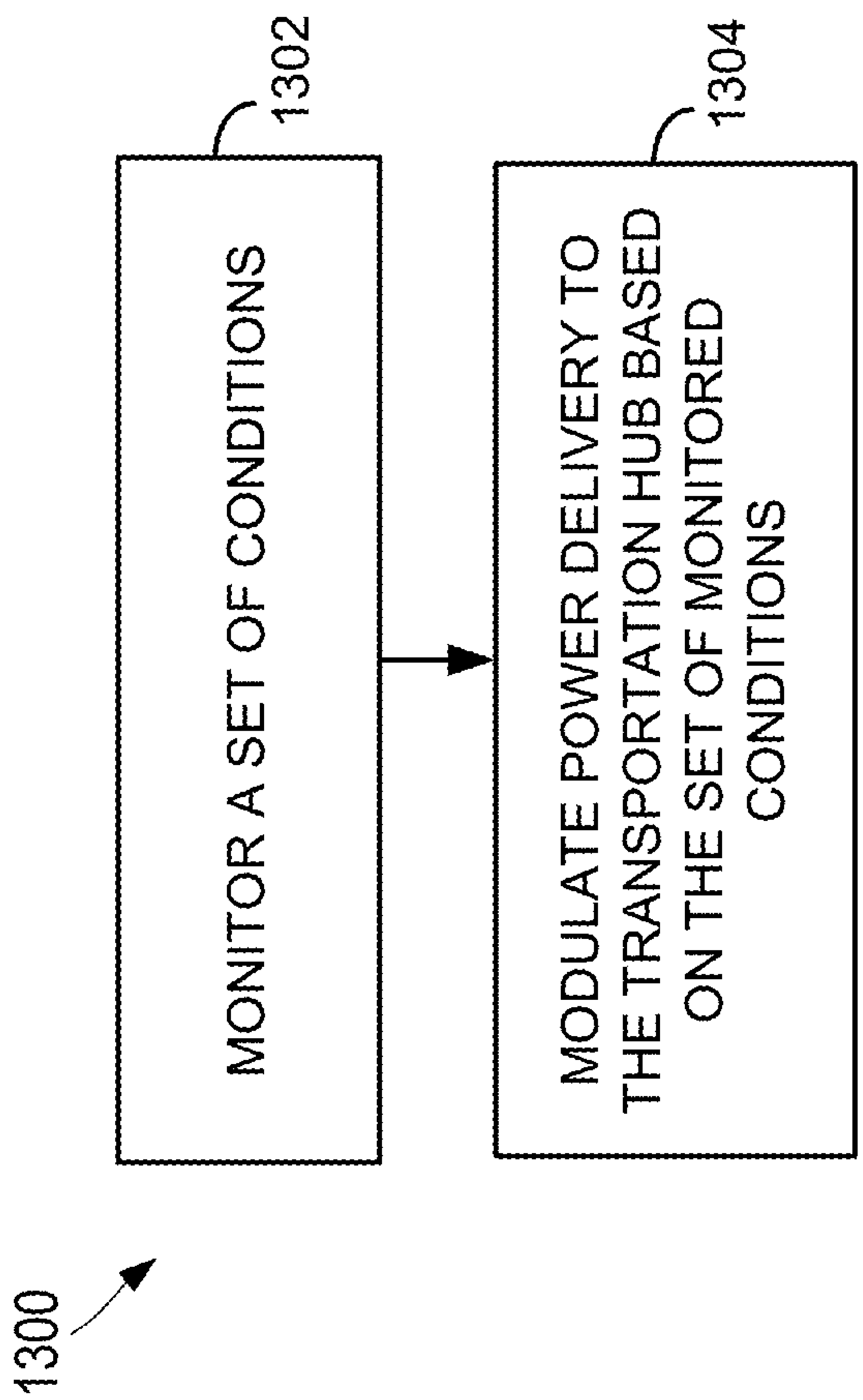
1300
MONITOR A SET OF CONDITIONS
1302
MODULATE POWER DELIVERY TO THE TRANSPORTATION HUB BASED ON THE SET OF MONITORED CONDITIONS
1304

FIGURE 13

BEHIND-THE-METER BRANCH LOADS FOR ELECTRICAL VEHICLE CHARGING

FIELD

This specification relates to a system using intermittent behind-the-meter power.

BACKGROUND

"Electrical grid" or "grid," as used herein, refers to a Wide Area Synchronous Grid (also known as an Interconnection), and is a regional scale or greater electric power grid that that operates at a synchronized frequency and is electrically tied together during normal system conditions. An electrical grid delivers electricity from generation stations to consumers. An electrical grid includes: (i) generation stations that produce electrical power at large scales for delivery through the grid, (ii) high voltage transmission lines that carry that power from the generation stations to demand centers, and (iii) distribution networks carry that power to individual customers.

FIG. **1** illustrates a typical electrical grid, such as a North American Interconnection or the synchronous grid of Continental Europe (formerly known as the UCTE grid). The electrical grid of FIG. **1** can be described with respect to the various segments that make up the grid.

A generation segment **102** includes one or more generation stations that produce utility-scale electricity (typically >50MW), such as a nuclear plant **102***a*, a coal plant **102***b*, a wind power station (i.e., wind farm) **102***c*, and/or a photovoltaic power station (i.e., a solar farm) **102***d*. Generation stations are differentiated from building-mounted and other decentralized or local wind or solar power applications because they supply power at the utility level and scale (>50MW), rather than to a local user or users. The primary purpose of generation stations is to produce power for distribution through the grid, and in exchange for payment for the supplied electricity. Each of the generation stations **102***a-d* includes power generation equipment **102***e-h*, respectively, typically capable of supply utility-scale power (>50MW). For example, the power generation equipment **102***g* at wind power station **102***c* includes wind turbines, and the power generation equipment **102***h* at photovoltaic power station **102***d* includes photovoltaic panels.

Each of the generation stations **102***a-d* may further includes station electrical equipment **102***i*-**1** respectively. Station electrical equipment **102***i*-**1** are each illustrated in FIG. **1** as distinct elements for simplified illustrative purposes only and may, alternatively or additionally, be distributed throughout the power generation equipment, **102***e-h*, respectively. For example, at wind power station **102***c*, each wind turbine may include transformers, frequency converters, power converters, and/or electrical filters. Energy generated at each wind turbine may be collected by distribution lines along strings of wind turbines and move through collectors, switches, transformers, frequency converters, power converters, electrical filters, and/or other station electrical equipment before leaving the wind power station **102***c*. Similarly, at photovoltaic power station **102***d*, individual photovoltaic panels and/or arrays of photovoltaic panels may include inverters, transformers, frequency converters, power converters, and/or electrical filters. Energy generated at each photovoltaic panel and/or array may be collected by distribution lines along the photovoltaic panels and move through collectors, switches, transformers, frequency converters, power converters, electrical filters, and/or other station electrical equipment before leaving the photovoltaic power station **102***d*.

Each generation station **102***a-d* may produce AC or DC electrical current which is then typically stepped up to a higher AC voltage before leaving the respective generation station. For example, wind turbines may typically produce AC electrical energy at 600V to 700V, which may then be stepped up to 34.5 kV before leaving the generation station **102***d*. In some cases, the voltage may be stepped up multiple times and to a different voltage before exiting the generation station **102***c*. As another example, photovoltaic arrays may produce DC voltage at 600V to 900V, which is then inverted to AC voltage and may be stepped up to 34.5 kV before leaving the generation station **102***d*. In some cases, the voltage may be stepped up multiple times and to a different voltage before exiting the generation station **102***d*.

Upon exiting the generation segment **102**, electrical power generated at generation stations **102***a-d* passes through a respective Point of Interconnection ("POI") **103** between a generation station (e.g., **102***a-d*) and the rest of the grid. A respective POI **103** represents the point of connection between a generation station's (e.g. **102***a-d*) equipment and a transmission system (e.g., transmission segment **104**) associated with electrical grid. In some cases, at the POI **103**, generated power from generation stations **102***a-d* may be stepped up at transformer systems **103***e-h* to high voltage scales suitable for long-distance transmission along transmission lines **104***a*. Typically, the generate electrical energy leaving the POI **103** will be at 115 kV AC or above, but in some cases it may be as low as, for example, 69 kV for shorter distance transmissions along transmission lines **104***a*. Each of transformer systems **103***e-h* may be a single transformer or may be multiple transformers operating in parallel or series and may be co-located or located in geographically distinct locations. Each of the transformer systems **103***e-h* may include substations and other links between the generation stations **102***a-d* and the transmission lines **104***a*.

A key aspect of the POI **103** is that this is where generation-side metering occurs. One or more utility-scale generation-side meters **103***a-d* (e.g., settlement meters) are located at settlement metering points at the respective POI **103** for each generation station **102***a-d*. The utility-scale generation-side meters **103***a-d* measure power supplied from generation stations **102***a-d* into the transmission segment **104** for eventual distribution throughout the grid.

For electricity consumption, the price consumers pay for power distributed through electric power grids is typically composed of, among other costs, Generation, Administration, and Transmission & Distribution ("T&D") costs. T&D costs represent a significant portion of the overall price paid by consumers for electricity. These costs include capital costs (land, equipment, substations, wire, etc.), costs associated with electrical transmission losses, and operation and maintenance costs.

For utility-scale electricity supply, operators of generation stations (e.g., **102***a-d*) are paid a variable market price for the amount of power the operator generates and provides to the grid, which is typically determined via a power purchase agreement (PPA) between the generation station operator and a grid operator. The amount of power the generation station operator generates and provides to the grid is measured by utility-scale generation-side meters (e.g., **103***a-d*) at settlement metering points. As illustrated in FIG. **1**, the utility-scale generation-side meters **103***a-d* are shown on a low side of the transformer systems **103***e-h*), but they may alternatively be located within the transformer systems **103***e-h* or on the high side of the transformer systems **103***e-h*. A key aspect of a utility-scale generation-side meter is that it is able to meter the power supplied from a specific generation station into the grid. As a result, the grid operator can use that information to calculate and process payments for power supplied from the generation station to the grid. That price paid for the power supplied from the generation station is then subject to T&D costs, as well as other costs, in order to determine the price paid by consumers.

After passing through the utility-scale generation-side meters in the POI **103**, the power originally generated at the generation stations **102***a-d* is transmitted onto and along the transmission lines **104***a* in the transmission segment **104**. Typically, the electrical energy is transmitted as AC at 115 kV+ or above, though it may be as low as 69 kV for short transmission distances. In some cases, the transmission segment **104** may include further power conversions to aid in efficiency or stability. For example, transmission segment **104** may include high-voltage DC ("HVDC") portions (along with conversion equipment) to aid in frequency synchronization across portions of the transmission segment **104**. As another example, transmission segment **104** may include transformers to step AC voltage up and then back down to aid in long distance transmission (e.g., 230 kV, 500 kV, 765 kV, etc.).

Power generated at the generation stations **104***a-d* is ultimately destined for use by consumers connected to the grid. Once the energy has been transmitted along the transmission segment **104**, the voltage will be stepped down by transformer systems **105***a-c* in the step down segment **105** so that it can move into the distribution segment **106**.

In the distribution segment **106**, distribution networks **106***a-c* take power that has been stepped down from the transmission lines **104***a* and distribute it to local customers, such as local sub-grids (illustrated at **106***a*), industrial customers, including large EV charging networks (illustrated at **106***b*), and/or residential and retail customers, including individual EV charging stations (illustrated at **106***c*). Customer meters **106***d*, **106***f* measure the power used by each of the grid-connected customers in distribution networks **106***a-c*. Customer meters **106***d* are typically load meters that are unidirectional and measure power use. Some of the local customers in the distribution networks **106***a-d* may have local wind or solar power systems **106***e* owned by the customer. As discussed above, these local customer power systems **106***e* are decentralized and supply power directly to the customer(s). Customers with decentralized wind or solar power systems **106***e* may have customer meters **106***f* that are bidirectional or net-metering meters that can track when the local customer power systems **106***e* produce power in excess of the customer's use, thereby allowing the utility to provide a credit to the customer's monthly electricity bill. Customer meters **106***d*, **106***f* differ from utility-scale generation-side meters (e.g., settlement meters) in at least the following characteristics: design (electro-mechanical or electronic vs current transformer), scale (typically less than 1600 amps vs. typically greater than 50MW; typically less than 600V vs. typically greater than 14 kV), primary function (use vs. supply metering), economic purpose (credit against use vs payment for power), and location (in a distribution network at point of use vs. at a settlement metering point at a Point of Interconnection between a generation station and a transmission line).

To maintain stability of the grid, the grid operator strives to maintain a balance between the amount of power entering the grid from generation stations (e.g., **102***a-d*) and the amount of grid power used by loads (e.g., customers in the distribution segment **106**). In order to maintain grid stability and manage congestion, grid operators may take steps to reduce the supply of power arriving from generation stations (e.g., **102***a-d*) when necessary (e.g., curtailment). Particularly, grid operators may decrease the market price paid for generated power to dis-incentivize generation stations (e.g., **102***a-d*) from generating and supplying power to the grid. In some cases, the market price may even go negative such that generation station operators must pay for power they allow into the grid. In addition, some situations may arise where grid operators explicitly direct a generation station (e.g., **102***a-d*) to reduce or stop the amount of power the station is supplying to the grid.

Power market fluctuations, power system conditions (e.g., power factor fluctuation or generation station startup and testing), and operational directives resulting in reduced or discontinued generation all can have disparate effects on renewal energy generators and can occur multiple times in a day and last for indeterminate periods of time. Curtailment, in particular, is particularly problematic.

According to the National Renewable Energy Laboratory's Technical Report TP-6A20-60983 (March 2014):

> [C]urtailment [is] a reduction in the output of a generator from what it could otherwise produce given available resources (e.g., wind or sunlight), typically on an involuntary basis. Curtailments can result when operators or utilities command wind and solar generators to reduce output to minimize transmission congestion or otherwise manage the system or achieve the optimal mix of resources. Curtailment of wind and solar resources typically occurs because of transmission congestion or lack of transmission access, but it can also occur for reasons such as excess generation during low load periods that could cause baseload generators to reach minimum generation thresholds, because of voltage or interconnection issues, or to maintain frequency requirements, particularly for small, isolated grids. Curtailment is one among many tools to maintain system energy balance, which can also include grid capacity, hydropower and thermal generation, demand response, storage, and institutional changes. Deciding which method to use is primarily a matter of economics and operational practice.
>
> "Curtailment" today does not necessarily mean what it did in the early 2000s. Two separate changes in the electric sector have shaped curtailment practices since that time: the utility-scale deployment of wind power, which has no fuel cost, and the evolution of wholesale power markets. These simultaneous changes have led to new operational challenges but have also expanded the array of market-based tools for addressing them.
>
> Practices vary significantly by region and market design. In places with centrally-organized wholesale power markets and experience with wind power, manual wind energy curtailment processes are increasingly being replaced by transparent offer-based market mechanisms that base dispatch on economics. Market protocols that dispatch generation based on economics can also result in renewable energy plants generating less than what they could potentially produce with available wind or sunlight. This is often referred to by grid operators by other terms, such as "downward dispatch." In places served primarily by vertically integrated utilities, power purchase agreements (PPAs) between the utility and the wind developer increasingly contain financial provisions for curtailment contingencies.

Some reductions in output are determined by how a wind operator values dispatch versus non-dispatch. Other curtailments of wind are determined by the grid operator in response to potential reliability events. Still other curtailments result from overdevelopment of wind power in transmission-constrained areas.

Dispatch below maximum output (curtailment) can be more of an issue for wind and solar generators than it is for fossil generation units because of differences in their cost structures. The economics of wind and solar generation depend on the ability to generate electricity whenever there is sufficient sunlight or wind to power their facilities.

Because wind and solar generators have substantial capital costs but no fuel costs (i.e., minimal variable costs), maximizing output improves their ability to recover capital costs. In contrast, fossil generators have higher variable costs, such as fuel costs. Avoiding these costs can, depending on the economics of a specific generator, to some degree reduce the financial impact of curtailment, especially if the generator's capital costs are included in a utility's rate base.

Curtailment may result in available energy being wasted because solar and wind operators have zero variable cost (which may not be true to the same extent for fossil generation units which can simply reduce the amount of fuel that is being used). With wind generation, in particular, it may also take some time for a wind farm to become fully operational following curtailment. As such, until the time that the wind farm is fully operational, the wind farm may not be operating with optimum efficiency and/or may not be able to provide power to the grid.

SUMMARY

In an example, a system includes a transportation hub electrically coupled to a BTM power source via a branch line. The transportation hub may receive behind-the-meter ("BTM") power from the BTM power source. The system may also include a datacenter control system configured to modulate power delivery to the transportation hub based on a set of monitored conditions. The set of monitored conditions may include BTM power availability at the transportation hub.

In another example, a method involves monitoring, by a datacenter control system, a set of conditions. The set of conditions may include behind-the-meter ("BTM") power availability at a transportation hub. The transportation hub is electrically coupled to a BTM power source via a branchline and configured to receive BTM power from the BTM power source. The method may further involve modulating, by the datacenter control system, power delivery to the transportation hub based on the set of monitored conditions.

In a further example, non-transitory computer-readable medium is described that is configured to store instructions, that when executed by a computing system, causes the computing system to perform functions consistent with the method steps described above.

Other aspects of the present invention will be apparent from the following description and claims.

BRIEF DESCRIPTION OF THE FIGURES

FIG. **1** shows a typical electrical grid.

FIG. **2** shows a behind-the-meter arrangement, including one or more flexible datacenters, according to one or more example embodiments.

FIG. **3** shows a block diagram of a remote master control system, according to one or more example embodiments.

FIG. **4** a block diagram of a generation station, according to one or more example embodiments.

FIG. **5** shows a block diagram of a flexible datacenter, according to one or more example embodiments.

FIG. **6**A shows a structural arrangement of a flexible datacenter, according to one or more example embodiments.

FIG. **6**B shows a set of computing systems arranged in a straight configuration, according to one or more example embodiments.

FIG. **7** shows a control distribution system for a flexible datacenter, according to one or more example embodiments.

FIG. **8** shows a control distribution system for a fleet of flexible datacenters, according to one or more example embodiments.

FIG. **9** shows a queue distribution system for a traditional datacenter and a flexible datacenter, according to one or more example embodiments.

FIG. **10**A shows a method of dynamic power consumption at a flexible datacenter using behind-the-meter power, according to one or more example embodiments.

FIG. **10**B shows a method of dynamic power delivery at a flexible datacenter using behind-the-meter power, according to one or more example embodiments.

FIG. **11** shows a transportation hub coupled via a branch line to a generation station, according to one or more example embodiments.

FIG. **12** shows a block diagram of a system for modulating power delivery to a transportation hub, according to one or more embodiments.

FIG. **13** illustrates a method for modulating power delivery to a transportation hub, according to one or more embodiments.

DETAILED DESCRIPTION

Disclosed examples will now be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all of the disclosed examples are shown. Different examples may be described and should not be construed as limited to the examples set forth herein.

As discussed above, the market price paid to generation stations for supplying power to the grid often fluctuates due to various factors, including the need to maintain grid stability and based on current demand and usage by connected loads in distribution networks. Due to these factors, situations can arise where generation stations are offered substantially lower prices to deter an over-supply of power to the grid. Although these situations typically exist temporarily, generation stations are sometimes forced to either sell power to the grid at much lower prices or adjust operations to decrease the amount of power generated. Furthermore, some situations may even require generation stations to incur costs in order to offload power to the grid or to shut down generation temporarily.

The volatility in the market price offered for power supplied to the grid can be especially problematic for some types of generation stations. In particular, wind farms and some other types of renewable resource power producers may lack the ability to quickly adjust operations in response to changes in the market price offered for supplying power to the grid. As a result, power generation and management at some generation stations can be inefficient, which can frequently result in power being sold to the grid at low or negative prices. In some situations, a generation station may even opt to halt power generation temporarily to avoid such unfavorable pricing. As such, the time required to halt and to restart the power generation at a generation station can reduce the generation station's ability to take advantage of rising market prices for power supplied to the grid.

Example embodiments provided herein aim to assist generation stations in managing power generation operations and avoid unfavorable power pricing situations like those described above. In particular, example embodiments may involve providing a load that is positioned behind-the-meter ("BTM") and enabling the load to utilize power received behind-the-meter at a generation station in a timely manner.

For purposes herein, a generation station is considered to be configured for the primary purpose of generating utility-scale power for supply to the electrical grid (e.g., a Wide Area Synchronous Grid or a North American Interconnect).

In one embodiment, equipment located behind-the-meter ("BTM equipment") is equipment that is electrically connected to a generation station's power generation equipment behind (i.e., prior to) the generation station's POI with an electrical grid.

In one embodiment, behind-the-meter power ("BTM power") is electrical power produced by a generation station's power generation equipment and utilized behind (i.e., prior to) the generation station's POI with an electrical grid.

In another embodiment, equipment may be considered behind-the-meter if it is electrically connected to a generation station that is subject to metering by a utility-scale generation-side meter (e.g., settlement meter), and the BTM equipment receives power from the generation station, but the power received by the BTM equipment from the generation station has not passed through the utility-scale generation-side meter. In one embodiment, the utility-scale generation-side meter for the generation station is located at the generation station's POI. In another embodiment, the utility-scale generation-side meter for the generation station is at a location other than the POI for the generation station—for example, a substation between the generation station and the generation station's POI.

In another embodiment, power may be considered behind-the-meter if it is electrical power produced at a generation station that is subject to metering by a utility-scale generation-side meter (e.g., settlement meter), and the BTM power is utilized before being metered at the utility-scale generation-side meter. In one embodiment, the utility-scale generation-side meter for the generation station is located at the generation station's POI. In another embodiment, the utility-scale generation-side meter for the generation station is at a location other than the POI for the generation station—for example, a substation between the generation station and the generation station's POI.

In another embodiment, equipment may be considered behind-the-meter if it is electrically connected to a generation station that supplies power to a grid, and the BTM equipment receives power from the generation station that is not subject to T&D charges, but power received from the grid that is supplied by the generation station is subject to T&D charges.

In another embodiment, power may be considered behind-the-meter if it is electrical power produced at a generation station that supplies power to a grid, and the BTM power is not subject to T&D charges before being used by electrical equipment, but power received from the grid that is supplied by the generation station is subject to T&D charges.

In another embodiment, equipment may be considered behind-the-meter if the BTM equipment receives power generated from the generation station and that received power is not routed through the electrical grid before being delivered to the BTM equipment.

In another embodiment, power may be considered behind-the-meter if it is electrical power produced at a generation station, and BTM equipment receives that generated power, and that generated power received by the BTM equipment is not routed through the electrical grid before being delivered to the BTM equipment.

For purposes herein, BTM equipment may also be referred to as a behind-the-meter load ("BTM load") when the BTM equipment is actively consuming BTM power.

Beneficially, where BTM power is not subject to traditional T&D costs, a wind farm or other type of generation station can be connected to BTM loads which can allow the generation station to selectively avoid the adverse or less-than optimal cost structure occasionally associated with supplying power to the grid by shunting generated power to the BTM load.

An arrangement that positions and connects a BTM load to a generation station can offer several advantages. In such arrangements, the generation station may selectively choose whether to supply power to the grid or to the BTM load, or both. The operator of a BTM load may pay to utilize BTM power at a cost less than that charged through a consumer meter (e.g., **106***d*, **1060** located at a distribution network (e.g., **106***a-c*) receiving power from the grid. The operator of a BTM load may additionally or alternatively pay less than the market rate to consume excess power generated at the generation station during curtailment. As a result, the generation station may direct generated power based on the "best" price that the generation station can receive during a given time frame, and/or the lowest cost the generation station may incur from negative market pricing during curtailment. The "best" price may be the highest price that the generation station may receive for its generated power during a given duration, but can also differ within embodiments and may depend on various factors, such as a prior PPA. In one example, by having a behind-the-meter option available, a generation station may transition from supplying all generated power to the grid to supplying some or all generated power to one or more BTM loads when the market price paid for power by grid operators drops below a predefined threshold (e.g., the price that the operator of the BTM load is willing to pay the generation station for power). Thus, by having an alternative option for power consumption (i.e., one or more BTM loads), the generation station can selectively utilize the different options to maximize the price received for generated power. In addition, the generation station may also utilize a BTM load to avoid or reduce the economic impact in situations when supplying power to the grid would result in the generation station incurring a net cost.

Providing BTM power to a load can also benefit the BTM load operator. A BTM load may be able to receive and utilize BTM power received from the generation station at a cost that is lower than the cost for power from the grid (e.g., at a customer meter **106***d*, **1060**. This is primarily due to avoidance in T&D costs and the market effects of curtailment. As indicated above, the generation station may be willing to divert generated power to the BTM load rather than supplying the grid due to changing market conditions, or during maintenance periods, or for other non-market conditions. Furthermore, in some situations, the BTM load may even be able to obtain and utilize BTM power from a generation station at no cost or even at negative pricing since the generation station may be receiving tax credits (e.g., Production Tax Credits) for produced wind or is slow to self-curtail.

Another example of cost-effective use of BTM power is when the generation station **202** is selling power to the grid at a negative price that is offset by a production tax credit. In certain circumstances, the value of the production tax credit may exceed the price the generation station **202** would have to pay to the grid power to offload generation's station **202** generated power. Advantageously, one or more flexible datacenters **220** may take the generated power behind-the-meter, thereby allowing the generation station **202** to produce and obtain the production tax credit, while selling less power to the grid at the negative price.

Another example of cost-effective behind-the-meter power is when the generation station **202** is selling power to the grid at a negative price because the grid is oversupplied and/or the generation station **202** is instructed to stand down and stop producing altogether. A grid operator may select and direct certain generation stations to go offline and stop supplying power to the grid. Advantageously, one or more flexible datacenters may be used to take power behind-the-meter, thereby allowing the generation station **202** to stop supplying power to the grid, but still stay online and make productive use of the power generated.

Another example of beneficial behind-the-meter power use is when the generation station **202** is producing power that is, with reference to the grid, unstable, out of phase, or at the wrong frequency, or the grid is already unstable, out of phase, or at the wrong frequency. A grid operator may select certain generation stations to go either offline and stop producing power, or to take corrective action with respect to the grid power stability, phase, or frequency. Advantageously, one or more flexible datacenters **220** may be used to selectively consume power behind-the-meter, thereby allowing the generation station **202** to stop providing power to the grid and/or provide corrective feedback to the grid.

Another example of beneficial behind-the-meter power use is that cost-effective behind-the-meter power availability may occur when the generation station **202** is starting up or testing. Individual equipment in the power generation equipment **210** may be routinely offline for installation, maintenance, and/or service and the individual units must be tested prior to coming online as part of overall power generation equipment **210**. During such testing or maintenance time, one or more flexible datacenters may be intermittently powered by the one or more units of the power generation equipment **210** that are offline from the overall power generation equipment **210**.

Another example of beneficial behind-the-meter power use is that datacenter control systems at the flexible datacenters **220** may quickly ramp up and ramp down power consumption by computing systems in the flexible datacenters **220** based on power availability from the generation station **202**. For instance, if the grid requires additional power and signals the demand via a higher local price for power, the generation station **202** can supply the grid with power nearly instantly by having active flexible datacenters **220** quickly ramp down and turn off computing systems (or switch to a stored energy source), thereby reducing an active BTM load.

Another example of beneficial behind-the-meter power use is in new photovoltaic generation stations **202**. For example, it is common to design and build new photovoltaic generation stations with a surplus of power capacity to account for degradation in efficiency of the photovoltaic panels over the life of the generation stations. Excess power availability at the generation station can occur when there is excess local power generation and/or low grid demand. In high incident sunlight situations, a photovoltaic generation station **202** may generate more power than the intended capacity of generation station **202**. In such situations, a photovoltaic generation station **202** may have to take steps to protect its equipment from damage, which may include taking one or more photovoltaic panels offline or shunting their voltage to dummy loads or the ground. Advantageously, one or more flexible datacenters (e.g., the flexible datacenters **220**) may take power behind-the-meter at the Generations Station **202**, thereby allowing the generation station **202** to operate the power generation equipment **210** within operating ranges while the flexible datacenters **220** receive BTM power without transmission or distribution costs.

Thus, for at least the reasons described herein, arrangements that involves providing a BTM load as an alternative option for a generation station to direct its generated power to can serve as a mutually beneficial relationship in which both the generation station and the BTM load can economically benefit. The above-noted examples of beneficial use of BTM power are merely exemplary and are not intended to limit the scope of what one of ordinary skill in the art would recognize as benefits to unutilized BTM power capacity, BTM power pricing, or BTM power consumption.

Within example embodiments described herein, various types of utility-scale power producers may operate as generation stations **202** that are capable of supplying power to one or more loads behind-the-meter. For instance, renewable energy sources (e.g., wind, solar, hydroelectric, wave, water current, tidal), fossil fuel power generation sources (coal, natural gas), and other types of power producers (e.g., nuclear power) may be positioned in an arrangement that enables the intermittent supply of generated power behind-the-meter to one or more BTM loads. One of ordinary skill in the art will recognize that the generation station **202** may vary based on an application or design in accordance with one or more example embodiments.

In addition, the particular arrangement (e.g., connections) between the generation station and one or more BTM loads can vary within examples. In one embodiment, a generation station may be positioned in an arrangement wherein the generation station selectively supplies power to the grid and/or to one or more BTM loads. As such, power cost-analysis and other factors (e.g., predicted weather conditions, contractual obligations, etc.) may be used by the generation station, a BTM load control system, a remote master control system, or some other system or enterprise, to selectively output power to either the grid or to one or more BTM loads in a manner that maximizes revenue to the generation station. In such an arrangement, the generation station may also be able to supply both the grid and one or more BTM loads simultaneously. In some instances, the arrangement may be configured to allow dynamic manipulation of the percentage of the overall generated power that is supplied to each option at a given time. For example, in some time periods, the generation station may supply no power to the BTM load.

In addition, the type of loads that are positioned behind-the-meter can vary within example embodiments. In general, a load that is behind-the-meter may correspond to any type of load capable of receiving and utilizing power behind-the-meter from a generation station. Some examples of loads include, but are not limited to, datacenters and electric vehicle (EV) charging stations.

Preferred BTM loads are loads that can be subject to intermittent power supply because BTM power may be available intermittently. In some instances, the generation station may generate power intermittently. For example, wind power station **102***c* and/or photovoltaic power station **102***d* may only generate power when resource are available or favorable. Additionally or alternatively, BTM power availability at a generation station may only be available intermittently due to power market fluctuations, power system conditions (e.g., power factor fluctuation or generation station startup and testing), and/or operational directives from grid operators or generation station operators.

Some example embodiments of BTM loads described herein involve using one or more computing systems to serve as a BTM load at a generation station. In particular, the computing system or computing systems may receive power behind-the-meter from the generation station to perform various computational operations, such as processing or storing information, performing calculations, mining for cryptocurrencies, supporting blockchain ledgers, and/or executing applications, etc. Multiple computing systems positioned behind-the-meter may operate as part of a "flexible" datacenter that is configured to operate only intermittently and to receive and utilize BTM power to carry out various computational operations similar to a traditional datacenter. In particular, the flexible datacenter may include computing systems and other components (e.g., support infrastructure, a control system) configured to utilize BTM power from one or more generation stations. The flexible datacenter may be configured to use particular load ramping abilities (e.g., quickly increase or decrease power usage) to effectively operate during intermittent periods of time when power is available from a generation station and supplied to the flexible datacenter behind-the-meter, such as during situations when supplying generated power to the grid is not favorable for the generation station. In some instances, the amount of power consumed by the computing systems at a flexible datacenter can be ramped up and down quickly, and potentially with high granularity (i.e., the load can be changed in small increments if desired). This may be done based on monitored power system conditions or other information analyses as discussed herein. As recited above, this can enable a generation station to avoid negative power market pricing and to respond quickly to grid directives. And by extension, the flexible datacenter may obtain BTM power at a price lower than the cost for power from the grid.

Various types of computing systems can provide granular behind-the-meter ramping. Preferably, the computing systems utilizing BTM power is utilized to perform computational tasks that are immune to, or not substantially hindered by, frequent interruptions or slow-downs in processing as the computing systems ramp down or up. In some embodiments, a control system may be used to activate or de-activate one or more computing systems in an array of computing systems sited behind the meter. For example, the control system may provide control instructions to one or more blockchain miners (e.g., a group of blockchain miners), including instructions for powering on or off, adjusting frequency of computing systems performing operations (e.g., adjusting the processing frequency), adjusting the quantity of operations being performed, and when to operate within a low power mode (if available).

Within examples, a control system may correspond to a specialized computing system or may be a computing system within a flexible datacenter serving in the role of the control system. The location of the control system can vary within examples as well. For instance, the control system may be located at a flexible datacenter or physically separate from the flexible datacenter. In some examples, the control system may be part of a network of control systems that manage computational operations, power consumption, and other aspects of a fleet of flexible datacenters.

Some embodiments may involve using one or more control systems to direct time-insensitive (e.g., interruptible) computational tasks to computational hardware, such as central processing units (CPUs) and graphics processing units (GPUs), sited behind the meter, while other hardware is sited in front of the meter (i.e., consuming metered grid power via a customer meter (e.g., **106***d*, **1060**) and possibly remote from the behind-the-meter hardware. As such, parallel computing processes, such as Monte Carlo simulations, batch processing of financial transactions, graphics rendering, machine learning, neural network processing, queued operations, and oil and gas field simulation models, are good candidates for such interruptible computational operations.

FIG. **2** shows a behind-the-meter arrangement, including one or more flexible datacenters, according to one or more example embodiments. Dark arrows illustrate a typical power delivery direction. Consistent with FIG. **1**, the arrangement illustrates a generation station **202** in the generation segment **102** of a Wide-Area Synchronous Grid. The generation station **202** supplies utility-scale power (typically >50MW) via a generation power connection **250** to the Point of Interconnection **103** between the generation station **202** and the rest of the grid. Typically, the power supplied on connection **250** may be at 34.5 kV AC, but it may be higher or lower. Depending on the voltage at connection **250** and the voltage at transmission lines **104***a*, a transformer system **203** may step up the power supplied from the generation station **202** to high voltage (e.g., 115 kV+AC) for transmission over connection **252** and onto transmission lines **104***a* of transmission segment **104**. Grid power carried on the transmission segment **104** may be from generation station **202** as well as other generation stations (not shown). Also consistent with FIG. **1**, grid power is consumed at one or more distribution networks, including example distribution network **206**. Grid power may be taken from the transmission lines **104***a* via connector **254** and stepped down to distribution network voltages (e.g., typically 4 kV to 26 kV AC) and sent into the distribution networks, such as distribution network **206** via distribution line **256**. The power on distribution line **256** may be further stepped down (not shown) before entering individual consumer facilities such as a remote master control system **262** and/or traditional datacenters **260** via customer meters **206**A, which may correspond to customer meters **106***d* in FIG. **1**, or customer meters **106***f* in FIG. **1** if the respective consumer facility includes a local customer power system, such as **106***e* (not shown in FIG. **2**).

Consistent with FIG. **1**, power entering the grid from generation station **202** is metered by a utility-scale generation-side meter. A utility-scale generation-side meter **253** is shown on the low side of transformer system **203** and an alternative location is shown as **253**A on the high side of transformer system **203**. Both locations may be considered settlement metering points for the generation station **202** at the POI **103**. Alternatively, a utility-scale generation-side meter for the generation station **202** may be located at another location consistent with the descriptions of such meters provided herein.

Generation station **202** includes power generation equipment **210**, which may include, as examples, wind turbines and/or photovoltaic panels. Power generation equipment **210** may further include other electrical equipment, including but not limited to switches, busses, collectors, inverters, and power unit transformers (e.g., transformers in wind turbines).

As illustrated in FIG. **2**, generation station **202** is configured to connect with BTM equipment which may function as BTM loads. In the illustrated embodiment of FIG. **2**, the BTM equipment includes flexible datacenters **220**. Various configurations to supply BTM power to flexible datacenters **220** within the arrangement of FIG. **2** are described herein.

In one configuration, generated power may travel from the power generation equipment **210** over one or more connectors **230**A, **230**B to one or more electrical busses **240**A, **240**B, respectively. Each of the connectors **230**A, **230**B may be a switched connector such that power may be routed independently to **240**A and/or **240**B. For illustrative purposes only, connector **230**B is shown with an open switch, and connector **230**A is shown with a closed switch, but either or both may be reversed in some embodiments. Aspects of this configuration can be used in various embodiments when BTM power is supplied without significant power conversion to BTM loads.

In various configurations, the busses **240**A and **240**B may be separated by an open switch **240**C or combined into a common bus by a closed switch **240**C.

In another configuration, generated power may travel from the power generation equipment **210** to the high side of a local step-down transformer **214**. The generated power may then travel from the low side of the local step-down transformer **214** over one or more connectors **232**A, **232**B to the one or more electrical busses **240**A, **240**B, respectively. Each of the connectors **232**A, **232**B may be a switched connector such that power may be routed independently to **240**A and/or **240**B. For illustrative purposes only, connector **232**A is shown with an open switch, and connector **232**B is shown with a closed switch, but either or both may be reversed in some embodiments. Aspects of this configuration can be used when it is preferable to connect BTM power to the power generation equipment **210**, but the generated power must be stepped down prior to use at the BTM loads.

In another configuration, generated power may travel from the power generation equipment **210** to the low side of a local step-up transformer **212**. The generated power may then travel from the high side of the local step-up transformer **212** over one or more connectors **234**A, **234**B to the one or more electrical buses **240**A, **240**B, respectively. Each of the connectors **234**A, **234**B may be a switched connector such that power may be routed independently to **240**A and/or **240**B. For illustrative purposes only, both connectors **234**A, **234**B are shown with open switches, but either or both may be closed in some embodiments. Aspects of this configuration can be used when it is preferable to connect BTM power to the outbound connector **250** or the high side of the local step-up transformer **212**.

In another configuration, generated power may travel from the power generation equipment **210** to the low side of the local step-up transformer **212**. The generated power may then travel from the high side of the local step-up transformer **212** to the high side of local step-down transformer **213**. The generated power may then travel from the low side of the local step-down transformer **213** over one or more connectors **236**A, **236**B to the one or more electrical busses **240**A, **240**B, respectively. Each of the connectors **236**A, **236**B may be a switched connector such that power may be routed independently to **240**A and/or **240**B. For illustrative purposes only, both connectors **236**A, **236**B are shown with open switches, but either or both may be closed in some embodiments. Aspects of this configuration can be used when it is preferable to connect BTM power to the outbound connector **250** or the high side of the local step-up transformer **212**, but the power must be stepped down prior to use at the BTM loads.

In one embodiment, power generated at the generation station **202** may be used to power a generation station control system **216** located at the generation station **202**, when power is available. The generation station control system **216** may typically control the operation of the generation station **202**. Generated power used at the generation station control system **216** may be supplied from bus **240**A via connector **216**A and/or from bus **240**B via connector **216**B. Each of the connectors **216**A, **216**B may be a switched connector such that power may be routed independently to **240**A and/or **240**B. While the generation station control system **216** can consume BTM power when powered via bus **240**A or bus **240**B, the BTM power taken by the generation station control system **216** is insignificant in terms of rendering an economic benefit. Further, the generation station control system **216** is not configured to operate intermittently, as it generally must remain always on. Further still, the generation station control system **216** does not have the ability to quickly ramp a BTM load up or down.

In another embodiment, grid power may alternatively or additionally be used to power the generation station control system **216**. As illustrated here, metered grid power from a distribution network, such as distribution network **206** for simplicity of illustration purposes only, may be used to power generation station control system **216** over connector **216**C. Connector **216**C may be a switched connector so that metered grid power to the generation station control system **216** can be switched on or off as needed. More commonly, metered grid power would be delivered to the generation station control system **216** via a separate distribution network (not shown), and also over a switched connector. Any such grid power delivered to the generation station control system **216** is metered by a customer meter **206**A and subject to T&D costs.

In another embodiment, when power generation equipment **210** is in an idle or off state and not generating power, grid power may backfeed into generation station **202** through POI **103** and such grid power may power the generation station control system **216**.

In some configurations, an energy storage system **218** may be connected to the generation station **202** via connector **218**A, which may be a switched connector. For illustrative purposes only, connector **218**A is shown with an open switch but in some embodiments it may be closed. The energy storage system **218** may be connected to bus **240**A and/or bus **240**B and store energy produced by the power generation equipment **210**. The energy storage system may also be isolated from generation station **202** by switch **242**A. In times of need, such as when the power generation equipment in an idle or off state and not generating power, the energy storage system may feed power to, for example, the flexible datacenters **220**. The energy storage system may also be isolated from the flexible datacenters **220** by switch **242**B.

In a preferred embodiment, as illustrated, power generation equipment **210** supplies BTM power via connector **242** to flexible datacenters **220**. The BTM power used by the flexible datacenters **220** was generated by the generation station **202** and did not pass through the POI **103** or utility-scale generation-side meter **253**, and is not subject to T&D charges. Power received at the flexible datacenters **220** may be received through respective power input connectors

220A. Each of the respective connectors 220A may be switched connector that can electrically isolate the respective flexible datacenter 220 from the connector 242. Power equipment 220B may be arranged between the flexible datacenters 220 and the connector 242. The power equipment 220B may include, but is not limited to, power conditioners, unit transformers, inverters, and isolation equipment. As illustrated, each flexible datacenter 220 may be served by a respective power equipment 220B. However, in another embodiment, one power equipment 220B may serve multiple flexible datacenter 220.

In one embodiment, flexible datacenters 220 may be considered BTM equipment located behind-the-meter and electrically connected to the power generation equipment 210 behind (i.e., prior to) the generation station's POI 103 with the rest of the electrical grid.

In one embodiment, BTM power produced by the power generation equipment 210 is utilized by the flexible datacenters 220 behind (i.e., prior to) the generation station's POI with an electrical grid.

In another embodiment, flexible datacenters 220 may be considered BTM equipment located behind-the-meter as the flexible datacenters 220 are electrically connected to the generation station 202, and generation station 202 is subject to metering by utility-scale generation-side meter 253 (or 253A, or another utility-scale generation-side meter), and the flexible datacenters 220 receive power from the generation station 202, but the power received by the flexible datacenters 220 from the generation station 202 has not passed through a utility-scale generation-side meter. In this embodiment, the utility-scale generation-side meter 253 (or 253A) for the generation station 202 is located at the generation station's 202 POI 103. In another embodiment, the utility-scale generation-side meter for the generation station 202 is at a location other than the POI for the generation station 202—for example, a substation (not shown) between the generation station 202 and the generation station's POI 103.

In another embodiment, power from the generation station 202 is supplied to the flexible datacenters 220 as BTM power, where power produced at the generation station 202 is subject to metering by utility-scale generation-side meter 253 (or 253A, or another utility-scale generation-side meter), but the BTM power supplied to the flexible datacenters 220 is utilized before being metered at the utility-scale generation-side meter 253 (or 253A, or another utility-scale generation-side meter). In this embodiment, the utility-scale generation-side meter 253 (or 253A) for the generation station 202 is located at the generation station's 202 POI 103. In another embodiment, the utility-scale generation-side meter for the generation station 202 is at a location other than the POI for the generation station 202—for example, a substation (not shown) between the generation station 202 and the generation station's POI 103.

In another embodiment, flexible datacenters 220 may be considered BTM equipment located behind-the-meter as they are electrically connected to the generation station 202 that supplies power to the grid, and the flexible datacenters 220 receive power from the generation station 202 that is not subject to T&D charges, but power otherwise received from the grid that is supplied by the generation station 202 is subject to T&D charges.

In another embodiment, power from the generation station 202 is supplied to the flexible datacenters 220 as BTM power, where electrical power is generated at the generation station 202 that supplies power to a grid, and the generated power is not subject to T&D charges before being used by flexible datacenters 220, but power otherwise received from the connected grid is subject to T&D charges.

In another embodiment, flexible datacenters 220 may be considered BTM equipment located behind-the-meter because they receive power generated from the generation station 202 intended for the grid, and that received power is not routed through the electrical grid before being delivered to the flexible datacenters 220.

In another embodiment, power from the generation station 202 is supplied to the flexible datacenters 220 as BTM power, where electrical power is generated at the generation station 202 for distribution to the grid, and the flexible datacenters 220 receive that power, and that received power is not routed through the electrical grid before being delivered to the flexible datacenters 220.

In another embodiment, metered grid power may alternatively or additionally be used to power one or more of the flexible datacenters 220, or a portion within one or more of the flexible datacenters 220. As illustrated here for simplicity, metered grid power from a distribution network, such as distribution network 206, may be used to power one or more flexible datacenters 220 over connector 256A and/or 256B. Each of connector 256A and/or 256B may be a switched connector so that metered grid power to the flexible datacenters 220 can be switched on or off as needed. More commonly, metered grid power would be delivered to the flexible datacenters 220 via a separate distribution network (not shown), and also over switched connectors. Any such grid power delivered to the flexible datacenters 220 is metered by customer meters 206A and subject to T&D costs. In one embodiment, connector 256B may supply metered grid power to a portion of one or more flexible datacenters 220. For example, connector 256B may supply metered grid power to control and/or communication systems for the flexible datacenters 220 that need constant power and cannot be subject to intermittent BTM power. Connector 242 may supply solely BTM power from the generation station 202 to high power demand computing systems within the flexible datacenters 220, in which case at least a portion of each flexible datacenters 220 so connected is operating as a BTM load. In another embodiment, connector 256A and/or 256B may supply all power used at one or more of the flexible datacenters 220, in which case each of the flexible datacenters 220 so connected would not be operating as a BTM load.

In another embodiment, when power generation equipment 210 is in an idle or off state and not generating power, grid power may backfeed into generation station 202 through POI 103 and such grid power may power the flexible datacenters 220.

The flexible datacenters 220 are shown in an example arrangement relative to the generation station 202. Particularly, generated power from the generation station 202 may be supplied to the flexible datacenters 220 through a series of connectors and/or busses (e.g., 232B, 240B, 242, 220A). As illustrated, in other embodiments, connectors between the power generation equipment 210 and other components may be switched open or closed, allowing other pathways for power transfer between the power generation equipment 210 and components, including the flexible datacenters 220. Additionally, the connector arrangement shown is illustrative only and other circuit arrangements are contemplated within the scope of supplying BTM power to a BTM load at generation station 202. For example, there may be more or fewer transformers, or one or more of transformers 212, 213, 214 may be transformer systems with multiple steppings and/or may include additional power equipment including but not limited to power conditioners, filters, switches, inverters, and/or AC/DC-DC/AC isolators. As another example, metered grid power connections to flexible datacenters **220** are shown via both **256**A and **256**B; however, a single connection may connect one or more flexible datacenters **220** (or power equipment **220**B) to metered grid power and the one or more flexible datacenters **220** (or power equipment **220**B) may include switching apparatus to direct BTM power and/or metered grid power to control systems, communication systems, and/or computing systems as desired.

In some examples, BTM power may arrive at the flexible datacenters **220** in a three-phase AC format. As such, power equipment (e.g., power equipment **220**B) at one or more of the flexible datacenters **220** may enable each flexible datacenter **220** to use one or more phases of the power. For instance, the flexible datacenters **220** may utilize power equipment (e.g., power equipment **220**B, or alternatively or additionally power equipment that is part of the flexible datacenter **220**) to convert BTM power received from the generation station **202** for use at computing systems at each flexible datacenter **220**. In other examples, the BTM power may arrive at one or more of the flexible datacenters **220** as DC power. As such, the flexible datacenters **220** may use the DC power to power computing systems. In some such examples, the DC power may be routed through a DC-to-DC converter that is part of power equipment **220**B and/or flexibles datacenter **220**.

In some configurations, a flexible datacenter **220** may be arranged to only have access to power received behind-the-meter from a generation station **202**. In the arrangement of FIG. **2**, the flexible datacenters **220** may be arranged only with a connection to the generation station **202** and depend solely on power received behind-the-meter from the generation station **202**. Alternatively or additionally, the flexible datacenters **220** may receive power from energy storage system **218**.

In some configurations, one or more of the flexible datacenters **220** can be arranged to have connections to multiple sources that are capable of supplying power to a flexible datacenter **220**. To illustrate a first example, the flexible datacenters **220** are shown connected to connector **242**, which can be connected or disconnected via switches to the energy storage system **218** via connector **218**A, the generation station **202** via bus **240**B, and grid power via metered connector **256**A. In one embodiment, the flexible datacenters **220** may selectively use power received behind-the-meter from the generation station **202**, stored power supplied by the energy storage system **218**, and/or grid power. For instance, flexible datacenters **220** may use power stored in the energy storage system **218** when costs for using power supplied behind-the-meter from the generation station **202** are disadvantageous. By having access to the energy storage system **218** available, the flexible datacenters **220** may use the stored power and allow the generation station **202** to subsequently refill the energy storage system **218** when cost for power behind-the-meter is low. Alternatively, the flexible datacenters **220** may use power from multiple sources simultaneously to power different components (e.g., a first set and a second set of computing systems). Thus, the flexible datacenters **220** may leverage the multiple connections in a manner that can reduce the cost for power used by the computing systems at the flexible datacenters **220**. The flexible datacenters **220** control system or the remote master control system **262** may monitor power conditions and other factors to determine whether the flexible datacenters **220** should use power from either the generation station **202**, grid power, the energy storage system **218**, none of the sources, or a subset of sources during a given time range. Other arrangements are possible as well. For example, the arrangement of FIG. **2** illustrates each flexible datacenter **220** as connected via a single connector **242** to energy storage system **218**, generation station **202**, and metered grid power via **256**A. However, one or more flexible datacenters **220** may have independent switched connections to each energy source, allowing the one or more flexible datacenters **220** to operate from different energy sources than other flexible datacenters **220** at the same time.

The selection of which power source to use at a flexible datacenter (e.g., the flexible datacenters **220**) or another type of BTM load can change based on various factors, such as the cost and availability of power from both sources, the type of computing systems using the power at the flexible datacenters **220** (e.g., some systems may require a reliable source of power for a long period), the nature of the computational operations being performed at the flexible datacenters **220** (e.g., a high priority task may require immediate completion regardless of cost), and temperature and weather conditions, among other possible factors. As such, a datacenter control system at the flexible datacenters **220**, the remote master control system **262**, or another entity (e.g., an operator at the generation station **202**) may also influence and/or determine the source of power that the flexible datacenters **220** use at a given time to complete computational operations.

In some example embodiments, the flexible datacenters **220** may use power from the different sources to serve different purposes. For example, the flexible datacenters **220** may use metered power from grid power to power one or more systems at the flexible datacenters **220** that are configured to be always-on (or almost always on), such as a control and/or communication system and/or one or more computing systems (e.g., a set of computing systems performing highly important computational operations). The flexible datacenters **220** may use BTM power to power other components within the flexible datacenters **220**, such as one or more computing systems that perform less critical computational operations.

In some examples, one or more flexible datacenters **220** may be deployed at the generation station **202**. In other examples, flexible datacenters **220** may be deployed at a location geographically remote from the generation station **202**, while still maintaining a BTM power connection to the generation station **202**.

In another example arrangement, the generation station **202** may be connected to a first BTM load (e.g., a flexible datacenter **220**) and may supply power to additional BTM loads via connections between the first BTM load and the additional BTM loads (e.g., a connection between a flexible datacenter **220** and another flexible datacenter **220**).

The arrangement in FIG. **2**, and components included therein, are for non-limiting illustration purposes and other arrangements are contemplated in examples. For instance, in another example embodiment, the arrangement of FIG. **2** may include more or fewer components, such as more BTM loads, different connections between power sources and loads, and/or a different number of datacenters. In addition, some examples may involve one or more components within the arrangement of FIG. **2** being combined or further divided.

Within the arrangement of FIG. **2**, a control system, such as the remote master control system **262** or another component (e.g., a control system associated with the grid operator, the generation station control system **216**, or a datacenter control system associated with a traditional datacenter or one or more flexible datacenters) may use information to efficiently manage various operations of some of the components within the arrangement of FIG. **2**. For example, the remote master control system **262** or another component may manage distribution and execution of computational operations at one or more traditional datacenters **260** and/or flexible datacenters **220** via one or more information-processing algorithms. These algorithms may utilize past and current information in real-time to manage operations of the different components. These algorithms may also make some predictions based on past trends and information analysis. In some examples, multiple computing systems may operate as a network to process information.

Information used to make decisions may include economic and/or power-related information, such as monitored power system conditions. Monitored power system conditions may include one or more of excess power generation at a generation station **202**, excess power at a generation station **202** that a connected grid cannot receive, power generation at a generation station **202** subject to economic curtailment, power generation at a generation station **202** subject to reliability curtailment, power generation at a generation station **202** subject to power factor correction, low power generation at a generation station **202**, start up conditions at a generation station **202**, transient power generation conditions at a generation station **202**, or testing conditions where there is an economic advantage to using behind-the-meter power generation at a generation station **202**. These different monitored power system conditions can be weighted differently during processing and analysis.

In some examples, the information can include the cost for power from available sources (e.g., BTM power at the generation station **202** versus metered grid power) to enable comparisons to be made as to which power source costs less. In some instances, the information may include historic prices for power to enable the remote master control system **262** or another system to predict potential future prices in similar situations (e.g., the cost of power tends to trend upwards for grid power during warmer weather and peak-use hours). The information may also indicate the availability of power from the various sources (e.g., BTM power at the generation station **262**, the energy storage system **218** at the generation station **262**, and/or metered grid power).

In addition, the information may also include other data, including information associated with operations at components within the arrangement. For instance, the information may include data associated with performance of operations at the flexible datacenters **220** and the traditional datacenters **260**, such as the number of computational tasks currently being performed, the types of tasks being performed (e.g., type of computational operation, time-sensitivity, etc.), the number, types, and capabilities of available computing systems, the amount of computational tasks awaiting performance, and the types of computing systems at one or more datacenters, among others. The information may also include data specifying the conditions at one or more datacenters (e.g., whether or not the temperatures are in a desired range, the amount of power available within an energy storage system such as **218**), the amount of computational tasks awaiting performance in the queue of one or more of the datacenters, and the identities of the entities associated with the computational operations at one or more of the datacenters. Entities associated with computational operations may be, for example, owners of the datacenters, customers who purchase computational time at the datacenters, or other entities.

The information used by the remote master control system **262** or another component may include data associated with the computational operations to be performed, such as deadlines, priorities (e.g., high vs. low priority tasks), cost to perform based on required computing systems, the optimal computing systems (e.g., CPU vs GPU vs ASIC; processing unit capabilities, speeds, or frequencies, or instructional sets executable by the processing units) for performing each requested computational task, and prices each entity (e.g., company) is willing to pay for computational operations to be performed or otherwise supported via computing systems at a traditional datacenter **260** or a flexible datacenter **220**, among others. In addition, the information may also include other data (e.g., weather conditions at locations of datacenters or power sources, any emergencies associated with a datacenter or power source, or the current value of bids associated with an auction for computational tasks).

The information may be updated in-real time and used to make the different operational decisions within the arrangement of FIG. **2**. For instance, the information may help a component (e.g., the remote master control system **262** or a control system at a flexible datacenter **220**) determine when to ramp up or ramp down power use at a flexible datacenter **220** or when to switch one or more computing systems at a flexible datacenter **220** into a low power mode or to operate at a different frequency, among other operational adjustments. The information can additionally or alternatively help a component within the arrangement of FIG. **2** to determine when to transfer computational operations between computing systems or between datacenters based on various factors. In some instances, the information may also be used to determine when to temporarily stop performing a computational operation or when to perform a computational operation at multiple sites for redundancy or other reasons. The information may further be used to determine when to accept new computational operations from entities or when to temporarily suspend accepting new tasks to be performed due to lack of computing system availability.

The remote master control system **262** represents a computing system that is capable of obtaining, managing, and using the information described above to manage and oversee one or more operations within the arrangement of FIG. **2**. As such, the remote master control system **262** may be one or more computing systems configured to process all, or a subset of, the information described above, such as power, environment, computational characterization, and economic factors to assist with the distribution and execution of computing operations among one or more datacenters. For instance, the remote master control system **262** may be configured to obtain and delegate computational operations among one or more datacenters based on a weighted analysis of a variety of factors, including one or more of the cost and availability of power, the types and availability of the computing systems at each datacenter, current and predicted weather conditions at the different locations of flexible datacenters (e.g., flexible datacenters **220**) and generation stations (e.g., generation stations **202**), levels of power storage available at one or more energy storage systems (e.g., energy storage system **218**), and deadlines and other attributes associated with particular computational operations, among other possible factors. As such, the analysis of information performed by the remote master control system **262** may vary within examples. For instance, the remote master control system **262** may use real-time information to determine whether or not to route a computational operation to a particular flexible datacenter (e.g., a flexible datacenter

220) or to transition a computational operation between datacenters (e.g., from traditional datacenter **260** to a flexible datacenter **220**).

As shown in FIG. **2**, the generation station **202** may be able to supply power to the grid and/or BTM loads such as flexible datacenters **220**. With such a configuration, the generation station **202** may selectively provide power to the BTM loads and/or the grid based on economic and power availability considerations. For example, the generation station **202** may supply power to the grid when the price paid for the power exceeds a particular threshold (e.g., the power price offered by operators of the flexible datacenters **220**). In some instances, the operator of a flexible datacenter and the operator of a generation station capable of supplying BTM power to the flexible datacenter may utilize a predefined arrangement (e.g., a contract) that specifies a duration and/or price range when the generation station may supply power to the flexible datacenter.

The remote master control system **262** may be capable of directing one or more flexible datacenters **220** to ramp-up or ramp-down to desired power consumption levels, and/or to control cooperative action of multiple flexible datacenters by determining how to power each individual flexible datacenter **220** in accordance with operational directives (e.g., instructions). In some examples, desired power consumption levels can depend on monitored conditions, such as power availability, prices for power from one or more sources, and timelines for completing computational operations.

The configuration of the remote master control system **262** can vary within examples as further discussed with respect to FIGS. **2**, **3**, and **7-9**. The remote master control system **262** may operate as a single computing system or may involve a network of computing systems. Preferably, the remote master control system **262** is implemented across one or more servers in a fault-tolerant operating environment that ensures continuous uptime and connectivity by virtue of its distributed nature. Alternatively, although the remote master control system **262** is shown as a physically separate component arrangement for FIG. **2**, the remote master control system **262** may be combined with another component in other embodiments. To illustrate an example, the remote master control system **262** may operate as part of a flexible datacenter (e.g., a computing system or a datacenter control system of the flexible datacenter **220**), including sharing components with a flexible datacenter, sharing power with a flexible datacenter, and/or being co-located with a flexible datacenter.

In addition, the remote master control system **262** may communicate with components within the arrangement of FIG. **2** using various communication technologies, including wired and wireless communication technologies. For instance, the remote master control system **262** may use wired (not illustrated) or wireless communication to communicate with datacenter control systems or other computing systems at the flexible datacenters **220** and the traditional datacenters **260**. The remote master control system **262** may also communicate with entities inside or outside the arrangement of FIG. **2** and other components within the arrangement of FIG. **2** via wired or wireless communication. For instance, the remote master control system **262** may use wireless communication to obtain computational operations from entities seeking support for the computational operations at one or more datacenters in exchange for payment. The remote master control system **262** may communicate directly with the entities or may obtain the computational operations from the traditional datacenters **260**. For instance, an entity may submit jobs (e.g., computational operations) to one or more traditional datacenters **260**. The remote master control system **262** may determine that transferring one or more of the computational operations to a flexible datacenter **220** may better support the transferred computational operations. For example, the remote master control system **262** may determine that the transfer may enable the computational operations to be completed quicker and/or at a lower cost. In some examples, the remote master control system **262** may communicate with the entity to obtain approval prior to transferring the one or more computational operations.

The remote master control system **262** may also communicate with grid operators and/or an operator of generation station **202** to help determine power management strategies when distributing computational operations across the various datacenters. In addition, the remote master control system **262** may communicate with other sources, such as weather prediction systems, historical and current power price databases, and auction systems, etc.

In further examples, the remote master control system **262** or another computing system within the arrangement of FIG. **2** may use wired or wireless communication to submit bids within an auction that involves a bidder (e.g., the highest bid) obtaining computational operations or other tasks to be performed. Particularly, the remote master control system **262** may use the information discussed above to develop bids to obtain computing operations for performance at available computing systems at flexible datacenters (e.g., flexible datacenters **220**).

In the example arrangement shown in FIG. **2**, the flexible datacenters **220** represent example loads that can receive power behind-the-meter from the generation station **202**. In such a configuration, the flexible datacenters **220** may obtain and utilize power behind-the-meter from the generation station **202** to perform various computational operations. Performance of a computational operation may involve one or more computing systems providing resources useful in the computational operation. For instance, the flexible datacenters **220** may include one or more computing systems configured to store information, perform calculations and/or parallel processes, perform simulations, mine cryptocurrencies, and execute applications, among other potential tasks. The computing systems can be specialized or generic and can be arranged at each flexible datacenter **220** in a variety of ways (e.g., straight configuration, zig-zag configuration) as further discussed with respect to FIGS. **6A**, **6B**. Furthermore, although the example arrangement illustrated in FIG. **2** shows configurations where flexible datacenters **220** serve as BTM loads, other types of loads can be used as BTM loads within examples.

The arrangement of FIG. **2** includes the traditional datacenters **260** coupled to metered grid power. The traditional datacenters **260** using metered grid power to provide computational resources to support computational operations. One or more enterprises may assign computational operations to the traditional datacenters **260** with expectations that the datacenters reliably provide resources without interruption (i.e., non-intermittently) to support the computational operations, such as processing abilities, networking, and/or volatile storage. Similarly, one or more enterprises may also request computational operations to be performed by the flexible datacenters **220**. The flexible datacenters **220** differ from the traditional datacenters **260** in that the flexible datacenters **220** are arranged and/or configured to be connected to BTM power, are expected to operate intermittently, and are expected to ramp load (and thus computational capability) up or down regularly in response to control directives. In some examples, the flexible datacenters **220** and the traditional datacenters **260** may have similar configurations and may only differ based on the source(s) of power relied upon to power internal computing systems. Preferably, however, the flexible datacenters **220** include particular fast load ramping abilities (e.g., quickly increase or decrease power usage) and are intended and designed to effectively operate during intermittent periods of time.

FIG. **3** shows a block diagram of the remote master control system **300** according to one or more example embodiments. Remote master control system **262** may take the form of remote master control system **300**, or may include less than all components in remote master control system **300**, different components than in remote master control system **300**, and/or more components than in remote master control system **300**.

The remote master control system **300** may perform one or more operations described herein and may include a processor **302**, a data storage unit **304**, a communication interface **306**, a user interface **308**, an operations and environment analysis module **310**, and a queue system **312**. In other examples, the remote master control system **300** may include more or fewer components in other possible arrangements.

As shown in FIG. **3**, the various components of the remote master control system **300** can be connected via one or more connection mechanisms (e.g., a connection mechanism **314**). In this disclosure, the term "connection mechanism" means a mechanism that facilitates communication between two or more devices, systems, components, or other entities. For instance, a connection mechanism can be a simple mechanism, such as a cable, PCB trace, or system bus, or a relatively complex mechanism, such as a packet-based communication network (e.g., LAN, WAN, and/or the Internet). In some instances, a connection mechanism can include a non-tangible medium (e.g., where the connection is wireless).

As part of the arrangement of FIG. **2**, the remote master control system **300** (corresponding to remote master control system **262**) may perform a variety of operations, such as management and distribution of computational operations among datacenters, monitoring operational, economic, and environment conditions, and power management. For instance, the remote master control system **300** may obtain computational operations from one or more enterprises for performance at one or more datacenters. The remote master control system **300** may subsequently use information to distribute and assign the computational operations to one or more datacenters (e.g., the flexible datacenters **220**) that have the resources (e.g., particular types of computing systems and available power) available to complete the computational operations. In some examples, the remote master control system **300** may assign all incoming computational operation requests to the queue system **312** and subsequently assign the queued requests to computing systems based on an analysis of current market and power conditions.

Although the remote master control system **300** is shown as a single entity, a network of computing systems may perform the operations of the remote master control system **300** in some examples. For example, the remote master control system **300** may exist in the form of computing systems (e.g., datacenter control systems) distributed across multiple datacenters.

The remote master control system **300** may include one or more processors **302**. As such, the processor **302** may represent one or more general-purpose processors (e.g., a microprocessor) and/or one or more special-purpose processors (e.g., a digital signal processor (DSP)). In some examples, the processor **302** may include a combination of processors within examples. The processor **302** may perform operations, including processing data received from the other components within the arrangement of FIG. **2** and data obtained from external sources, including information such as weather forecasting systems, power market price systems, and other types of sources or databases.

The data storage unit **304** may include one or more volatile, non-volatile, removable, and/or non-removable storage components, such as magnetic, optical, or flash storage, and/or can be integrated in whole or in part with the processor **302**. As such, the data storage unit **304** may take the form of a non-transitory computer-readable storage medium, having stored thereon program instructions (e.g., compiled or non-compiled program logic and/or machine code) that, when executed by the processor **302**, cause the remote master control system **300** to perform one or more acts and/or functions, such as those described in this disclosure. Such program instructions can define and/or be part of a discrete software application. In some instances, the remote master control system **300** can execute program instructions in response to receiving an input, such as from the communication interface **306**, the user interface **308**, or the operations and environment analysis module **310**. The data storage unit **304** may also store other information, such as those types described in this disclosure.

In some examples, the data storage unit **304** may serve as storage for information obtained from one or more external sources. For example, data storage unit **304** may store information obtained from one or more of the traditional datacenters **260**, a generation station **202**, a system associated with the grid, and flexible datacenters **220**. As examples only, data storage **304** may include, in whole or in part, local storage, dedicated server-managed storage, network attached storage, and/or cloud-based storage, and/or combinations thereof.

The communication interface **306** can allow the remote master control system **300** to connect to and/or communicate with another component according to one or more protocols. For instance, the communication interface **306** may be used to obtain information related to current, future, and past prices for power, power availability, current and predicted weather conditions, and information regarding the different datacenters (e.g., current workloads at datacenters, types of computing systems available within datacenters, price to obtain power at each datacenter, levels of power storage available and accessible at each datacenter, etc.). In an example, the communication interface **306** can include a wired interface, such as an Ethernet interface or a high-definition serial-digital-interface (HD-SDI). In another example, the communication interface **406** can include a wireless interface, such as a cellular, satellite, WiMAX, or WI-FI interface. A connection can be a direct connection or an indirect connection, the latter being a connection that passes through and/or traverses one or more components, such as such as a router, switcher, or other network device. Likewise, a wireless transmission can be a direct transmission or an indirect transmission. The communication interface **306** may also utilize other types of wireless communication to enable communication with datacenters positioned at various locations.

The communication interface **306** may enable the remote master control system **300** to communicate with the components of the arrangement of FIG. **2**. In addition, the communication interface **306** may also be used to communicate with the various datacenters, power sources, and different enterprises submitting computational operations for the datacenters to support.

The user interface **308** can facilitate interaction between the remote master control system **300** and an administrator or user, if applicable. As such, the user interface **308** can include input components such as a keyboard, a keypad, a mouse, a touch-sensitive panel, a microphone, and/or a camera, and/or output components such as a display device (which, for example, can be combined with a touch-sensitive panel), a sound speaker, and/or a haptic feedback system. More generally, the user interface **308** can include hardware and/or software components that facilitate interaction between remote master control system **300** and the user of the system.

In some examples, the user interface **308** may enable the manual examination and/or manipulation of components within the arrangement of FIG. **2**. For instance, an administrator or user may use the user interface **308** to check the status of, or change, one or more computational operations, the performance or power consumption at one or more datacenters, the number of tasks remaining within the queue system **312**, and other operations. As such, the user interface **308** may provide remote connectivity to one or more systems within the arrangement of FIG. **2**.

The operations and environment analysis module **310** represents a component of the remote master control system **300** associated with obtaining and analyzing information to develop instructions/directives for components within the arrangement of FIG. **2**. The information analyzed by the operations and environment analysis module **310** can vary within examples and may include the information described above with respect predicting and/or directing the use of BTM power. For instance, the operations and environment analysis module **310** may obtain and access information related to the current power state of computing systems operating as part of the flexible datacenters **220** and other datacenters that the remote master control system **300** has access to. This information may be used to determine when to adjust power usage or mode of one or more computing systems. In addition, the remote master control system **300** may provide instructions a flexible datacenter **220** to cause a subset of the computing systems to transition into a low power mode to consume less power while still performing operations at a slower rate. The remote master control system **300** may also use power state information to cause a set of computing systems at a flexible datacenter **220** to operate at a higher power consumption mode. In addition, the remote master control system **300** may transition computing systems into sleep states or power on/off based on information analyzed by the operations and environment analysis module **310**.

In some examples, the operations and environment analysis module **310** may use location, weather, activity levels at the flexible datacenters or the generation station, and power cost information to determine control strategies for one or more components in the arrangement of FIG. **2**. For instance, the remote master control system **300** may use location information for one or more datacenters to anticipate potential weather conditions that could impact access to power. In addition, the operations and environment analysis module **310** may assist the remote master control system **300** determine whether to transfer computational operations between datacenters based on various economic and power factors.

The queue system **312** represents a queue capable of organizing computational operations to be performed by one or more datacenters. Upon receiving a request to perform a computational operation, the remote master control system **300** may assign the computational operation to the queue until one or more computing systems are available to support the computational operation. The queue system **312** may be used for organizing and transferring computational tasks in real time.

The organizational design of the queue system **312** may vary within examples. In some examples, the queue system **312** may organize indications (e.g., tags, pointers) to sets of computational operations requested by various enterprises. The queue system **312** may operate as a First-In-First-Out (FIFO) data structure. In a FIFO data structure, the first element added to the queue will be the first one to be removed. As such, the queue system **312** may include one or more queues that operate using the FIFO data structure.

In some examples, one or more queues within the queue system **312** may use other designs of queues, including rules to rank or organize queues in a particular manner that can prioritize some sets of computational operations over others. The rules may include one or more of an estimated cost and/or revenue to perform each set of computational operations, an importance assigned to each set of computational operations, and deadlines for initiating or completing each set of computational operations, among others. Examples using a queue system are further described below with respect to FIG. **9**.

In some examples, the remote master control system **300** may be configured to monitor one or more auctions to obtain computational operations for datacenters to support. Particularly, the remote master control system **300** may use resource availability and power prices to develop and submit bids to an external or internal auction system for the right to support particular computational operations. As a result, the remote master control system **300** may identify computational operations that could be supported at one or more flexible datacenters **220** at low costs.

FIG. **4** is a block diagram of a generation station **400**, according to one or more example embodiments. Generation station **202** may take the form of generation station **400**, or may include less than all components in generation station **400**, different components than in generation station **400**, and/or more components than in generation station **400**. The generation station **400** includes a power generation equipment **401**, a communication interface **408**, a behind-the-meter interface **406**, a grid interface **404**, a user interface **410**, a generation station control system **414**, and power transformation equipment **402**. power generation equipment **210** may take the form of power generation equipment **401**, or may include less than all components in power generation equipment **401**, different components than in power generation equipment **401**, and/or more components than in power generation equipment **401**. Generation station control system **216** may take the form of generation station control system **414**, or may include less than all components in generation station control system **414**, different components than in generation station control system **414**, and/or more components than in generation station control system **414**. Some or all of the components generation station **400** may be connected via a communication interface **516**. These components are illustrated in FIG. **4** to convey an example configuration for the generation station **400** (corresponding to generation station **202** shown in FIG. **2**). In other examples, the generation station **400** may include more or fewer components in other arrangements.

The generation station **400** can correspond to any type of grid-connected utility-scale power producer capable of supplying power to one or more loads. The size, amount of power generated, and other characteristics of the generation station **400** may differ within examples. For instance, the generation station **400** may be a power producer that provides power intermittently. The power generation may depend on monitored power conditions, such as weather at the location of the generation station **400** and other possible conditions. As such, the generation station **400** may be a temporary arrangement, or a permanent facility, configured to supply power. The generation station **400** may supply BTM power to one or more loads and supply metered power to the electrical grid. Particularly, the generation station **400** may supply power to the grid as shown in the arrangement of FIG. **2**.

The power generation equipment **401** represents the component or components configured to generate utility-scale power. As such, the power generation equipment **401** may depend on the type of facility that the generation station **400** corresponds to. For instance, the power generation equipment **401** may correspond to electric generators that transform kinetic energy into electricity. The power generation equipment **401** may use electromagnetic induction to generate power. In other examples, the power generation equipment **401** may utilize electrochemistry to transform chemical energy into power. The power generation equipment **401** may use the photovoltaic effect to transform light into electrical energy. In some examples, the power generation equipment **401** may use turbines to generate power. The turbines may be driven by, for example, wind, water, steam or burning gas. Other examples of power production are possible.

The communication interface **408** enable the generation station **400** to communicate with other components within the arrangement of FIG. **2**. As such, the communication interface **408** may operate similarly to the communication interface **306** of the remote master control system **300** and the communication interface **503** of the flexible datacenter **500**.

The generation station control system **414** may be one or more computing systems configured to control various aspects of the generation station **400**.

The BTM interface **406** is a module configured to enable the power generation equipment **401** to supply BTM power to one or more loads and may include multiple components. The arrangement of the BTM interface **406** may differ within examples based on various factors, such as the number of flexible datacenters **220** (or **500**) coupled to the generation station **400**, the proximity of the flexible datacenters **220** (or **500**), and the type of generation station **400**, among others. In some examples, the BTM interface **406** may be configured to enable power delivery to one or more flexible datacenters positioned near the generation station **400**. Alternatively, the BTM interface **406** may also be configured to enable power delivery to one or more flexible datacenters **220** (or **500**) positioned remotely from the generation station **400**.

The grid interface **404** is a module configured to enable the power generation equipment **401** to supply power to the grid and may include multiple components. As such, the grid interface **404** may couple to one or more transmission lines (e.g., transmission lines **404***a* shown in FIG. **2**) to enable delivery of power to the grid.

The user interface **410** represents an interface that enables administrators and/or other entities to communicate with the generation station **400**. As such, the user interface **410** may have a configuration that resembles the configuration of the user interface **308** shown in FIG. **3**. An operator may utilize the user interface **410** to control or monitor operations at the generation station **400**.

The power transformation equipment **402** represents equipment that can be utilized to enable power delivery from the power generation equipment **401** to the loads and to transmission lines linked to the grid. Example power transformation equipment **402** includes, but is not limited to, transformers, inverters, phase converters, and power conditioners.

FIG. **5** shows a block diagram of a flexible datacenter **500**, according to one or more example embodiments. Flexible datacenters **220** may take the form of flexible datacenter **500**, or may include less than all components in flexible datacenter **500**, different components than in flexible datacenter **500**, and/or more components than in flexible datacenter **500**. In the example embodiment shown in FIG. **5**, the flexible datacenter **500** includes a power input system **502**, a communication interface **503**, a datacenter control system **504**, a power distribution system **506**, a climate control system **508**, one or more sets of computing systems **512**, and a queue system **514**. These components are shown connected by a communication bus **528**. In other embodiments, the configuration of flexible datacenter **500** can differ, including more or fewer components. In addition, the components within flexible datacenter **500** may be combined or further divided into additional components within other embodiments.

The example configuration shown in FIG. **5** represents one possible configuration for a flexible datacenter. As such, each flexible datacenter may have a different configuration when implemented based on a variety of factors that may influence its design, such as location and temperature that the location, particular uses for the flexible datacenter, source of power supplying computing systems within the flexible datacenter, design influence from an entity (or entities) that implements the flexible datacenter, and space available for the flexible datacenter. Thus, the embodiment of flexible datacenter **220** shown in FIG. **2** represents one possible configuration for a flexible datacenter out of many other possible configurations.

The flexible datacenter **500** may include a design that allows for temporary and/or rapid deployment, setup, and start time for supporting computational operations. For instance, the flexible datacenter **500** may be rapidly deployed at a location near a source of generation station power (e.g., near a wind farm or solar farm). Rapid deployment may involve positioning the flexible datacenter **500** at a target location and installing and/or configuring one or more racks of computing systems within. The racks may include wheels to enable swift movement of the computing systems. Although the flexible datacenter **500** could theoretically be placed anywhere, transmission losses may be minimized by locating it proximate to BTM power generation.

The physical construction and layout of the flexible datacenter **500** can vary. In some instances, the flexible datacenter **500** may utilize a metal container (e.g., a metal container **602** shown in FIG. **6**A). In general, the flexible datacenter **500** may utilize some form of secure weatherproof housing designed to protect interior components from wind, weather, and intrusion. The physical construction and layout of example flexible datacenters are further described with respect to FIGS. **6**A-**6**B.

Within the flexible datacenter **500**, various internal components enable the flexible datacenter **500** to utilize power to perform some form of operations. The power input system

502 is a module of the flexible datacenter 500 configured to receive external power and input the power to the different components via assistance from the power distribution system 506. As discussed with respect to FIG. 2, the sources of external power feeding a flexible datacenter can vary in both quantity and type (e.g., the generation stations 202, 400, grid-power, energy storage systems). Power input system 502 includes a BTM power input sub-system 522, and may additionally include other power input sub-systems (e.g., a grid-power input sub-system 524 and/or an energy storage input sub-system 526). In some instances, the quantity of power input sub-systems may depend on the size of the flexible datacenter and the number and/or type of computing systems being powered.

In some embodiments, the power input system 502 may include some or all of flexible datacenter Power Equipment 220B. The power input system 502 may be designed to obtain power in different forms (e.g., single phase or three-phase behind-the-meter alternating current ("AC") voltage, and/or direct current ("DC") voltage). As shown, the power input system 502 includes a BTM power input sub-system 522, a grid power input sub-system 524, and an energy input sub-system 526. These sub-systems are included to illustrate example power input sub-systems that the flexible datacenter 500 may utilize, but other examples are possible. In addition, in some instances, these sub-systems may be used simultaneously to supply power to components of the flexible datacenter 500. The sub-systems may also be used based on available power sources.

In some implementations, the BTM power input sub-system 522 may include one or more AC-to-AC step-down transformers used to step down supplied medium-voltage AC to low voltage AC (e.g., 120V to 600V nominal) used to power computing systems 512 and/or other components of flexible datacenter 500. The power input system 502 may also directly receive single-phase low voltage AC from a generation station as BTM power, from grid power, or from a stored energy system such as energy storage system 218. In some implementations, the power input system 502 may provide single-phase AC voltage to the datacenter control system 504 (and/or other components of flexible datacenter 500) independent of power supplied to computing systems 512 to enable the datacenter control system 504 to perform management operations for the flexible datacenter 500. For instance, the grid power input sub-system 524 may use grid power to supply power to the datacenter control system 504 to ensure that the datacenter control system 504 can perform control operations and communicate with the remote master control system 300 (or 262) during situations when BTM power is not available. As such, the datacenter control system 504 may utilize power received from the power input system 502 to remain powered to control the operation of flexible datacenter 500, even if the computational operations performed by the computing system 512 are powered intermittently. In some instances, the datacenter control system 504 may switch into a lower power mode to utilize less power while still maintaining the ability to perform some functions.

The power distribution system 506 may distribute incoming power to the various components of the flexible datacenter 500. For instance, the power distribution system 506 may direct power (e.g., single-phase or three-phase AC) to one or more components within flexible datacenter 500. In some embodiments, the power distribution system 506 may include some or all of flexible datacenter Power Equipment 220B.

In some examples, the power input system 502 may provide three phases of three-phase AC voltage to the power distribution system 506. The power distribution system 506 may controllably provide a single phase of AC voltage to each computing system or groups of computing systems 512 disposed within the flexible datacenter 500. The datacenter control system 504 may controllably select which phase of three-phase nominal AC voltage that power distribution system 506 provides to each computing system 512 or groups of computing systems 512. This is one example manner in which the datacenter control system 504 may modulate power delivery (and load at the flexible datacenter 500) by ramping-up flexible datacenter 500 to fully operational status, ramping-down flexible datacenter 500 to offline status (where only datacenter control system 504 remains powered), reducing load by withdrawing power delivery from, or reducing power to, one or more of the computing systems 512 or groups of the computing systems 512, or modulating power factor correction for the generation station 300 (or 202) by controllably adjusting which phases of three-phase nominal AC voltage are used by one or more of the computing systems 512 or groups of the computing systems 512. The datacenter control system 504 may direct power to certain sets of computing systems based on computational operations waiting for computational resources within the queue system 514. In some embodiments, the flexible datacenter 500 may receive BTM DC power to power the computing systems 512.

One of ordinary skill in the art will recognize that a voltage level of three-phase AC voltage may vary based on an application or design and the type or kind of local power generation. As such, a type, kind, or configuration of the operational AC-to-AC step down transformer (not shown) may vary based on the application or design. In addition, the frequency and voltage level of three-phase AC voltage, single-phase AC voltage, and DC voltage may vary based on the application or design in accordance with one or more embodiments.

As discussed above, the datacenter control system 504 may perform operations described herein, such as dynamically modulating power delivery to one or more of the computing systems 512 disposed within flexible datacenter 500. For instance, the datacenter control system 504 may modulate power delivery to one or more of the computing systems 512 based on various factors, such as BTM power availability or an operational directive from a generation station 262 or 300 control system, a remote master control system 262 or 300, or a grid operator. In some examples, the datacenter control system 504 may provide computational operations to sets of computing systems 512 and modulate power delivery based on priorities assigned to the computational operations. For instance, an important computational operation (e.g., based on a deadline for execution and/or price paid by an entity) may be assigned to a particular computing system or set of computing systems 512 that has the capacity, computational abilities to support the computational operation. In addition, the datacenter control system 504 may also prioritize power delivery to the computing system or set of computing systems 512.

In some example, the datacenter control system 504 may further provide directives to one or more computing systems to change operations in some manner. For instance, the datacenter control system 504 may cause one or more computing systems 512 to operate at a lower or higher frequency, change clock cycles, or operate in a different power consumption mode (e.g., a low power mode). These abilities may vary depending on types of computing systems

512 available at the flexible datacenter 500. As a result, the datacenter control system 504 may be configured to analyze the computing systems 512 available either on a periodic basis (e.g., during initial set up of the flexible datacenter 500) or in another manner (e.g., when a new computational operation is assigned to the flexible datacenter 500).

The datacenter control system 504 may also implement directives received from the remote master control system 262 or 300. For instance, the remote master control system 262 or 300 may direct the flexible datacenter 500 to switch into a low power mode. As a result, one or more of the computing systems 512 and other components may switch to the low power mode in response.

The datacenter control system 504 may utilize the communication interface 503 to communicate with the remote master control system 262 or 300, other datacenter control systems of other datacenters, and other entities. As such, the communication interface 503 may include components and operate similar to the communication interface 306 of the remote master control system 300 described with respect to FIG. 4.

The flexible datacenter 500 may also include a climate control system 508 to maintain computing systems 512 within a desired operational temperature range. The climate control system 508 may include various components, such as one or more air intake components, an evaporative cooling system, one or more fans, an immersive cooling system, an air conditioning or refrigerant cooling system, and one or more air outtake components. One of ordinary skill in the art will recognize that any suitable heat extraction system configured to maintain the operation of computing systems 512 within the desired operational temperature range may be used.

The flexible datacenter 500 may further include an energy storage system 510. The energy storage system 510 may store energy for subsequent use by computing systems 512 and other components of flexible datacenter 500. For instance, the energy storage system 510 may include a battery system. The battery system may be configured to convert AC voltage to DC voltage and store power in one or more storage cells. In some instances, the battery system may include a DC-to-AC inverter configured to convert DC voltage to AC voltage, and may further include an AC phase-converter, to provide AC voltage for use by flexible datacenter 500.

The energy storage system 510 may be configured to serve as a backup source of power for the flexible datacenter 500. For instance, the energy storage system 510 may receive and retain power from a BTM power source at a low cost (or no cost at all). This low-cost power can then be used by the flexible datacenter 500 at a subsequent point, such as when BTM power costs more. Similarly, the energy storage system 510 may also store energy from other sources (e.g., grid power). As such, the energy storage system 510 may be configured to use one or more of the sub-systems of the power input system 502.

In some examples, the energy storage system 510 may be external to the flexible datacenter 500. For instance, the energy storage system 510 may be an external source that multiple flexible datacenters utilize for back-up power.

The computing systems 512 represent various types of computing systems configured to perform computational operations. Performance of computational operations include a variety of tasks that one or more computing systems may perform, such as data storage, calculations, application processing, parallel processing, data manipulation, cryptocurrency mining, and maintenance of a distributed ledger, among others. As shown in FIG. 5, the computing systems 512 may include one or more CPUs 516, one or more GPUs 518, and/or one or more Application-Specific Integrated Circuits (ASIC's) 520. Each type of computing system 512 may be configured to perform particular operations or types of operations.

Due to different performance features and abilities associated with the different types of computing systems, the datacenter control system 504 may determine, maintain, and/or relay this information about the types and/or abilities of the computing systems, quantity of each type, and availability to the remote master control system 262 or 300 on a routine basis (e.g., periodically or on-demand). This way, the remote master control system 262 or 300 may have current information about the abilities of the computing systems 512 when distributing computational operations for performance at one or more flexible datacenters. Particularly, the remote master control system 262 or 300 may assign computational operations based on various factors, such as the types of computing systems available and the type of computing systems required by each computing operation, the availability of the computing systems, whether computing systems can operate in a low power mode, and/or power consumption and/or costs associated with operating the computing systems, among others.

The quantity and arrangement of these computing systems 512 may vary within examples. In some examples, the configuration and quantity of computing systems 512 may depend on various factors, such as the computational tasks that are performed by the flexible datacenter 500. In other examples, the computing systems 512 may include other types of computing systems as well, such as DSPs, SIMDs, neural processors, and/or quantum processors.

As indicated above, the computing systems 512 can perform various computational operations, including in different configurations. For instance, each computing system may perform a particular computational operation unrelated to the operations performed at other computing systems. Groups of the computing systems 512 may also be used to work together to perform computational operations.

In some examples, multiple computing systems may perform the same computational operation in a redundant configuration. This redundant configuration creates a back-up that prevents losing progress on the computational operation in situations of a computing failure or intermittent operation of one or more computing systems. In addition, the computing systems 512 may also perform computational operations using a check point system. The check point system may enable a first computing system to perform operations up to a certain point (e.g., a checkpoint) and switch to a second computing system to continue performing the operations from that certain point. The check point system may also enable the datacenter control system 504 to communicate statuses of computational operations to the remote master control system 262 or 300. This can further enable the remote master control system 262 300 to transfer computational operations between different flexible datacenters allowing computing systems at the different flexible datacenters to resume support of computational operations based on the check points.

The queue system 514 may operate similar to the queue system 312 of the remote master control system 300 shown in FIG. 3. Particularly, the queue system 514 may help store and organize computational tasks assigned for performance at the flexible datacenter 500. In some examples, the queue system 514 may be part of a distributed queue system such that each flexible datacenter in a fleet of flexible datacenter includes a queue, and each queue system **514** may be able to communicate with other queue systems. In addition, the remote master control system **262** or **300** may be configured to assign computational tasks to the queues located at each flexible datacenter (e.g., the queue system **514** of the flexible datacenter **500**). As such, communication between the remote master control system **262** or **300** and the datacenter control system **504** and/or the queue system **514** may allow organization of computational operations for the flexible datacenter **500** to support.

FIG. **6**A shows another structural arrangement for a flexible datacenter, according to one or more example embodiments. The particular structural arrangement shown in FIG. **6**A may be implemented at flexible datacenter **500**. The illustration depicts the flexible datacenter **500** as a mobile container **702** equipped with the power input system **502**, the power distribution system **506**, the climate control system **508**, the datacenter control system **504**, and the computing systems **512** arranged on one or more racks **604**. These components of flexible datacenter **500** may be arranged and organized according to an example structural region arrangement. As such, the example illustration represents one possible configuration for the flexible datacenter **500**, but others are possible within examples.

As discussed above, the structural arrangement of the flexible datacenter **500** may depend on various factors, such as the ability to maintain temperature within the mobile container **602** within a desired temperature range. The desired temperature range may depend on the geographical location of the mobile container **602** and the type and quantity of the computing systems **512** operating within the flexible datacenter **500** as well as other possible factors. As such, the different design elements of the mobile container **602** including the inner contents and positioning of components may depend on factors that aim to maximize the use of space within mobile container **602**, lower the amount of power required to cool the computing systems **512**, and make setup of the flexible datacenter **500** efficient. For instance, a first flexible datacenter positioned in a cooler geographic region may include less cooling equipment than a second flexible datacenter positioned in a warmer geographic region.

As shown in FIG. **6**A, the mobile container **602** may be a storage trailer disposed on permanent or removable wheels and configured for rapid deployment. In other embodiments, the mobile container **602** may be a storage container (not shown) configured for placement on the ground and potentially stacked in a vertical or horizontal manner (not shown). In still other embodiments, the mobile container **602** may be an inflatable container, a floating container, or any other type or kind of container suitable for housing a mobile flexible datacenter. As such, the flexible datacenter **500** may be rapidly deployed on site near a source of unutilized behind-the-meter power generation. And in still other embodiments, the flexible datacenter **500** might not include a mobile container. For example, the flexible datacenter **500** may be situated within a building or another type of stationary environment.

FIG. **6**B shows the computing systems **512** in a straight-line configuration for installation within the flexible datacenter **500**, according to one or more example embodiments. As indicated above, the flexible datacenter **500** may include a plurality of racks **604**, each of which may include one or more computing systems **512** disposed therein. As discussed above, the power input system **502** may provide three phases of AC voltage to the power distribution system **506**. In some examples, the power distribution system **506** may controllably provide a single phase of AC voltage to each computing system **512** or group of computing systems **512** disposed within the flexible datacenter **500**. As shown in FIG. **6**B, for purposes of illustration only, eighteen total racks **604** are divided into a first group of six racks **606**, a second group of six racks **608**, and a third group of six racks **610**, where each rack contains eighteen computing systems **512**. The power distribution system (**506** of FIG. **5**) may, for example, provide a first phase of three-phase AC voltage to the first group of six racks **606**, a second phase of three-phase AC voltage to the second group of six racks **608**, and a third phase of three-phase AC voltage to the third group of six racks **610**. In other embodiments, the quantity of racks and computing systems can vary.

FIG. **7** shows a control distribution system **700** of the flexible datacenter **500** according to one or more example embodiments. The system **700** includes a grid operator **702**, a generation station control system **216**, a remote master control system **300**, and a flexible datacenter **500**. As such, the system **700** represents one example configuration for controlling operations of the flexible datacenter **500**, but other configurations may include more or fewer components in other arrangements.

The datacenter control system **504** may independently, or cooperatively with one or more of the generation station control system **414**, the remote master control system **300**, and the grid operator **702**, modulate power at the flexible datacenter **500**. During operations, the power delivery to the flexible datacenter **500** may be dynamically adjusted based on conditions or operational directives. The conditions may correspond to economic conditions (e.g., cost for power, aspects of computational operations to be performed), power-related conditions (e.g., availability of the power, the sources offering power), demand response, and/or weather-related conditions, among others.

The generation station control system **414** may be one or more computing systems configured to control various aspects of a generation station (not independently illustrated, e.g., **216** or **400**). As such, the generation station control system **414** may communicate with the remote master control system **300** over a networked connection **706** and with the datacenter control system **704** over a networked or other data connection **708**.

As discussed with respect to FIGS. **2** and **3**, the remote master control system **300** can be one or more computing systems located offsite, but connected via a network connection **710** to the datacenter control system **504**. The remote master control system **300** may provide supervisory controls or override control of the flexible datacenter **500** or a fleet of flexible datacenters (not shown).

The grid operator **702** may be one or more computing systems that are configured to control various aspects of the power grid (not independently illustrated) that receives power from the generation station. The grid operator **702** may communicate with the generation station control system **300** over a networked or other data connection **712**.

The datacenter control system **504** may monitor BTM power conditions at the generation station and determine when a datacenter ramp-up condition is met. The BTM power availability may include one or more of excess local power generation, excess local power generation that the grid cannot accept, local power generation that is subject to economic curtailment, local power generation that is subject to reliability curtailment, local power generation that is subject to power factor correction, conditions where the cost for power is economically viable (e.g., low cost to obtain power), low priced power, situations where local power generation is prohibitively low, start up situations, transient situations, or testing situations where there is an economic advantage to using locally generated behind-the-meter power generation, specifically power available at little to no cost and with no associated transmission or distribution losses or costs. For example, a datacenter control system may analyze future workload and near term weather conditions at the flexible datacenter.

In some instances, the datacenter ramp-up condition may be met if there is sufficient behind-the-meter power availability and there is no operational directive from the generation station control system **414**, the remote master control system **300**, or the grid operator **702** to go offline or reduce power. As such, the datacenter control system **504** may enable **714** the power input system **502** to provide power to the power distribution system **506** to power the computing systems **512** or a subset thereof.

The datacenter control system **504** may optionally direct one or more computing systems **512** to perform predetermined computational operations (e.g., distributed computing processes). For example, if the one or more computing systems **512** are configured to perform distributed computing operations, the datacenter control system **504** may direct them to perform distributed computing operations (e.g., hashing operations) for a specific application, such as, for example, Bitcoin, Litecoin, or Ethereum. Alternatively, one or more computing systems **512** may be configured to perform high-throughput computing operations and/or high performance computing operations.

The remote master control system **300** may specify to the datacenter control system **504** what sufficient behind-the-meter power availability constitutes, or the datacenter control system **504** may be programmed with a predetermined preference or criteria on which to make the determination independently. For example, in certain circumstances, sufficient behind-the-meter power availability may be less than that required to fully power the entire flexible datacenter **500**. In such circumstances, the datacenter control system **504** may provide power to only a subset of computing systems, or operate the plurality of computing systems in a lower power mode, that is within the sufficient, but less than full, range of power that is available or to maximize profitability. In addition, the computing systems **512** may adjust operational frequency, such as performing more or less processes during a given duration.

While the flexible datacenter **500** is online and operational, a datacenter ramp-down condition may be met when there is insufficient or anticipated to be insufficient, behind-the-meter power availability or there is an operational directive from the generation station control system **414**, the remote master control system **300**, or the grid operator **702**. The datacenter control system **504** may monitor and determine when there is insufficient, or anticipated to be insufficient, behind-the-meter power availability. As noted above, sufficiency may be specified by the remote master control system **300** or the datacenter control system **504** may be programmed with a predetermined preference or criteria on which to make the determination independently.

An operational directive may be based on current dispatchability, forward looking forecasts for when behind-the-meter power is, or is expected to be, available, economic considerations, reliability considerations, operational considerations, or the discretion of the generation station control system **414**, the remote master control system **300**, or the grid operator **702**. For example, the generation station control system **414**, the remote master control system **300**, or the grid operator **702** may issue an operational directive to flexible datacenter **500** to go offline and power down. When the datacenter ramp-down condition is met, the datacenter control system **504** may disable power delivery to the plurality of computing systems (e.g., **512**). The datacenter control system **504** may disable **714** the power input system **502** from providing power (e.g., three-phase nominal AC voltage) to the power distribution system **506** to power down the computing systems **512** while the datacenter control system **504** remains powered and is capable of returning service to operating mode at the flexible datacenter **500** when behind-the-meter power becomes available again.

While the flexible datacenter **500** is online and operational, changed conditions or an operational directive may cause the datacenter control system **504** to modulate power consumption by the flexible datacenter **500**. The datacenter control system **504** may determine, or the generation station control system **414**, the remote master control system **300**, or the grid operator **702** may communicate, that a change in local conditions may result in less power generation, availability, or economic feasibility, than would be necessary to fully power the flexible datacenter **500**. In such situations, the datacenter control system **504** may take steps to reduce or stop power consumption by the flexible datacenter **500** (other than that required to maintain operation of datacenter control system **504**).

Alternatively, the generation station control system **414**, the remote master control system **300**, or the grid operator **702**, may issue an operational directive to reduce power consumption for any reason, the cause of which may be unknown. In response, the datacenter control system **504** may dynamically reduce or withdraw power delivery to one or more computing systems **512** to meet the dictate. The datacenter control system **504** may controllably provide three-phase nominal AC voltage to a smaller subset of computing systems (e.g., **512**) to reduce power consumption. The datacenter control system **504** may dynamically reduce the power consumption of one or more computing systems by reducing their operating frequency or forcing them into a lower power mode through a network directive.

One of ordinary skill in the art will recognize that datacenter control system **504** may be configured to have a number of different configurations, such as a number or type or kind of the computing systems **512** that may be powered, and in what operating mode, that correspond to a number of different ranges of sufficient and available behind-the-meter power. As such, the datacenter control system **504** may modulate power delivery over a variety of ranges of sufficient and available unutilized behind-the-meter power availability.

FIG. **8** shows a control distribution system **800** of a fleet of flexible datacenters according to one or more example embodiments. The control distribution system **800** of the flexible datacenter **500** shown and described with respect to FIG. **7** may be extended to a fleet of flexible datacenters as illustrated in FIG. **8**. For example, a first generation station (not independently illustrated), such as a wind farm, may include a first plurality of flexible datacenters **802**, which may be collocated or distributed across the generation station. A second generation station (not independently illustrated), such as another wind farm or a solar farm, may include a second plurality of flexible datacenters **804**, which may be collocated or distributed across the generation station. One of ordinary skill in the art will recognize that the number of flexible datacenters deployed at a given station and the number of stations within the fleet may vary based on an application or design in accordance with one or more example embodiments.

The remote master control system **300** may provide directive to datacenter control systems of the fleet of flexible datacenters in a similar manner to that shown and described with respect to FIG. **7**, with the added flexibility to make high level decisions with respect to fleet that may be counterintuitive to a given station. The remote master control system **300** may make decisions regarding the issuance of operational directives to a given generation station based on, for example, the status of each generation station where flexible datacenters are deployed, the workload distributed across fleet, and the expected computational demand required for one or both of the expected workload and predicted power availability. In addition, the remote master control system **300** may shift workloads from the first plurality of flexible datacenters **802** to the second plurality of flexible datacenters **804** for any reason, including, for example, a loss of BTM power availability at one generation station and the availability of BTM power at another generation station. As such, the remote master control system **300** may communicate with the generation station control systems **806**A, **806**B to obtain information that can be used to organize and distribute computational operations to the fleets of flexible datacenters **802**, **804**.

FIG. **9** shows a queue distribution arrangement for a traditional datacenter **902** and a flexible datacenter **500**, according to one or more example embodiments. The arrangement of FIG. **9** includes a flexible datacenter **500**, a traditional datacenter **902**, a queue system **312**, a set of communication links **916**, **918**, **920**A, **920**B, and the remote master control system **300**. The arrangement of FIG. **9** represents an example configuration scheme that can be used to distribute computing operations using a queue system **312** between the traditional datacenter **902** and one or more flexible datacenters. In other examples, the arrangement of FIG. **9** may include more or fewer components in other potential configurations. For instance, the arrangement of FIG. **9** may not include the queue system **312** or may include routes that bypass the queue system **312**.

The arrangement of FIG. **9** may enable computational operations requested to be performed by entities (e.g., companies). As such, the arrangement of FIG. **9** may use the queue system **312** to organize incoming computational operations requests to enable efficient distribution to the flexible datacenter **500** and the critical traditional datacenter **902**. Particularly, the arrangement of FIG. **9** may use the queue system **312** to organize sets of computational operations thereby increasing the speed of distribution and performance of the different computational operations among datacenters. As a result, the use of the queue system **312** may reduce time to complete operations and reduce costs.

In some examples, one or more components, such as the datacenter control system **504**, the remote master control system **300**, the queue system **312**, or the control system **936**, may be configured to identify situations that may arise where using the flexible datacenter **500** can reduce costs or increase productivity of the system, as compared to using the traditional datacenter **902** for computational operations. For example, a component within the arrangement of FIG. **9** may identify when using behind-the-meter power to power the computing systems **512** within the flexible datacenter **500** is at a lower cost compared to using the computing systems **934** within the traditional datacenter **902** that are powered by grid power. Additionally, a component in the arrangement of FIG. **9** may be configured to determine situations when offloading computational operations from the traditional datacenter **902** indirectly (i.e., via the queue system **312**) or directly (i.e., bypassing the queue system **312**) to the flexible datacenter **500** can increase the performance allotted to the computational operations requested by an entity (e.g., reduce the time required to complete time-sensitive computational operations).

In some examples, the datacenter control system **504** may monitor activity of the computing systems **512** within the flexible datacenter **500** and use the respective activity levels to determine when to obtain computational operations from the queue system **312**. For instance, the datacenter control system **504** may analyze various factors prior to requesting or accessing a set of computational operations or an indication of the computational operations for the computing systems **512** to perform. The various factors may include power availability at the flexible datacenter **500** (e.g., either stored or from a BTM source), availability of the computing systems **512** (e.g., percentage of computing systems available), type of computational operations available, estimated cost to perform the computational operations at the flexible datacenter **500**, cost for power, cost for power relative to cost for grid power, and instructions from other components within the system, among others. The datacenter control system **504** may analyze one or more of the factors when determining whether to obtain a new set of computational operations for the computing systems **512** to perform. In such a configuration, the datacenter control system **504** manages the activity of the flexible datacenter **500**, including determining when to acquire new sets of computational operations when capacity among the computing systems **512** permit.

In other examples, a component (e.g., the remote master control system **300**) within the system may assign or distribute one or more sets of computational operations organized by the queue system **312** to the flexible datacenter **500**. For example, the remote master control system **300** may manage the queue system **312**, including the distribution of computational operations organized by the queue system **312** to the flexible datacenter **500** and the traditional datacenter **902**. The remote master control system **300** may utilize to information described with respect to the Figures above to determine when to assign computational operations to the flexible datacenter **500**.

The traditional datacenter **902** may include a power input system **930**, a power distribution system **932**, a datacenter control system **936**, and a set of computing systems **934**. The power input system **930** may be configured to receive power from a power grid and distribute the power to the computing systems **934** via the power distribution system **932**. The datacenter control system **936** may monitor activity of the computing systems **934** and obtain computational operations to perform from the queue system **312**. The datacenter control system **936** may analyze various factors prior to requesting or accessing a set of computational operations or an indication of the computational operations for the computing systems **934** to perform. A component (e.g., the remote master control system **300**) within the arrangement of FIG. **9** may assign or distribute one or more sets of computational operations organized by the queue system **312** to the traditional datacenter **902**.

The communication link **916** represents one or more links that may serve to connect the flexible datacenter **500**, the traditional datacenter **902**, and other components within the system (e.g., the remote master control system **300**, the queue system **312**—connections not shown). In particular, the communication link **916** may enable direct or indirect communication between the flexible datacenter **500** and the traditional datacenter **902**. The type of communication link **916** may depend on the locations of the flexible datacenter

500 and the traditional datacenter 902. Within embodiments, different types of communication links can be used, including but not limited to WAN connectivity, cloud-based connectivity, and wired and wireless communication links.

The queue system 312 represents an abstract data type capable of organizing computational operation requests received from entities. As each request for computational operations are received, the queue system 312 may organize the request in some manner for subsequent distribution to a datacenter. Different types of queues can make up the queue system 312 within embodiments. The queue system 312 may be a centralized queue that organizes all requests for computational operations. As a centralized queue, all incoming requests for computational operations may be organized by the centralized queue.

In other examples, the queue system 312 may be distributed consisting of multiple queue sub-systems. In the distributed configuration, the queue system 312 may use multiple queue sub-systems to organize different sets of computational operations. Each queue sub-system may be used to organize computational operations based on various factors, such as according to deadlines for completing each set of computational operations, locations of enterprises submitting the computational operations, economic value associated with the completion of computational operations, and quantity of computing resources required for performing each set of computational operations. For instance, a first queue sub-system may organize sets of non-intensive computational operations and a second queue sub-system may organize sets of intensive computational operations. In some examples, the queue system 312 may include queue sub-systems located at each datacenter. This way, each datacenter (e.g., via a datacenter control system) may organize computational operations obtained at the datacenter until computing systems are able to start executing the computational operations. In some examples, the queue system 312 may move computational operations between different computing systems or different datacenters in real-time.

Within the arrangement of FIG. 9, the queue system 312 is shown connected to the remote master control system 300 via the communication link 918. In addition, the queue system 312 is also shown connected to the flexible datacenter via the communication 920A and to the traditional datacenter 902 via the communication link 920B. The communication links 918, 920A, 920B may be similar to the communication link 916 and can be various types of communication links within examples.

The queue system 312 may include a computing system configured to organize and maintain queues within the queue system 312. In another example, one or more other components of the system may maintain and support queues within the queue system 312. For instance, the remote master control system 300 may maintain and support the queue system 312. In other examples, multiple components may maintain and support the queue system 312 in a distributed manner, such as a blockchain configuration.

In some embodiments, the remote master control system 300 may serve as an intermediary that facilitates all communication between flexible datacenter 500 and the traditional datacenter 902. Particularly, the traditional datacenter 902 or the flexible datacenter 500 might need to transmit communications to the remote master control system 300 in order to communicate with the other datacenter. As also shown, the remote master control system 300 may connect to the queue system 312 via the communication link 918. Computational operations may be distributed between the queue system 312 and the remote master control system 300 via the communication link 918. The computational operations may be transferred in real-time and mid-performance from one datacenter to another (e.g., from the traditional datacenter 902 to the flexible datacenter 500). In addition, the remote master control system 300 may manage the queue system 312, including providing resources to support queues within the queue system 312.

As a result, the remote master control system 300 may offload some or all of the computational operations assigned to the traditional datacenter 902 to the flexible datacenter 500. This way, the flexible datacenter 500 can reduce overall computational costs by using the behind-the-meter power to provide computational resources to assist traditional datacenter 902. The remote master control system 300 may use the queue system 312 to temporarily store and organize the offloaded computational operations until a flexible datacenter (e.g., the flexible datacenter 500) is available to perform them. The flexible datacenter 500 consumes behind-the-meter power without transmission or distribution costs, which lowers the costs associated with performing computational operations originally assigned to the traditional datacenter 902. The remote master control system 300 may further communicate with the flexible datacenter 500 via communication link 922 and the traditional datacenter 902 via the communication link 924.

FIG. 10A shows method 1000 of dynamic power consumption at a flexible datacenter using behind-the-meter power according to one or more example embodiments. Other example methods may be used to manipulate the power delivery to one or more flexible datacenters.

In step 1010, the datacenter control system, the remote master control system, or another computing system may monitor behind-the-meter power availability. In some embodiments, monitoring may include receiving information or an operational directive from the generation station control system or the grid operator corresponding to behind-the-meter power availability.

In step 1020, the datacenter control system or the remote master control system 300 may determine when a datacenter ramp-up condition is met. In some embodiments, the datacenter ramp-up condition may be met when there is sufficient behind-the-meter power availability and there is no operational directive from the generation station to go offline or reduce power.

In step 1030, the datacenter control system may enable behind-the-meter power delivery to one or more computing systems. In some instances, the remote mater control system may directly enable BTM power delivery to computing systems within the flexible system without instructing the datacenter control system.

In step 1040, once ramped-up, the datacenter control system or the remote master control system may direct one or more computing systems to perform predetermined computational operations. In some embodiments, the predetermined computational operations may include the execution of one or more distributed computing processes, parallel processes, and/or hashing functions, among other types of processes.

While operational, the datacenter control system, the remote master control system, or another computing system may receive an operational directive to modulate power consumption. In some embodiments, the operational directive may be a directive to reduce power consumption. In such embodiments, the datacenter control system or the remote master control system may dynamically reduce power delivery to one or more computing systems or dynamically reduce power consumption of one or more computing systems. In other embodiments, the operational directive may be a directive to provide a power factor correction factor. In such embodiments, the datacenter control system or the remote master control system may dynamically adjust power delivery to one or more computing systems to achieve a desired power factor correction factor. In still other embodiments, the operational directive may be a directive to go offline or power down. In such embodiments, the datacenter control system may disable power delivery to one or more computing systems.

FIG. **10**B shows method **1050** of dynamic power delivery to a flexible datacenter using behind-the-meter power according to one or more embodiments. In step **1060**, the datacenter control system or the remote master control system may monitor behind-the-meter power availability. In certain embodiments, monitoring may include receiving information or an operational directive from the generation station control system or the grid operator corresponding to behind-the-meter power availability.

In step **1070**, the datacenter control system or the remote master control system may determine when a datacenter ramp-down condition is met. In certain embodiments, the datacenter ramp-down condition may be met when there is insufficient behind-the-meter power availability or anticipated to be insufficient behind-the-meter power availability or there is an operational directive from the generation station to go offline or reduce power.

In step **1080**, the datacenter control system may disable behind-the-meter power delivery to one or more computing systems. In step **1090**, once ramped-down, the datacenter control system remains powered and in communication with the remote master control system so that it may dynamically power the flexible datacenter when conditions change.

One of ordinary skill in the art will recognize that a datacenter control system may dynamically modulate power delivery to one or more computing systems of a flexible datacenter based on behind-the-meter power availability or an operational directive. The flexible datacenter may transition between a fully powered down state (while the datacenter control system remains powered), a fully powered up state, and various intermediate states in between. In addition, flexible datacenter may have a blackout state, where all power consumption, including that of the datacenter control system is halted. However, once the flexible datacenter enters the blackout state, it will have to be manually rebooted to restore power to datacenter control system. Generation station conditions or operational directives may cause flexible datacenter to ramp-up, reduce power consumption, change power factor, or ramp-down.

FIG. **11** shows a transportation hub coupled via a branch line to a generation station, according to one or more example embodiments. The arrangement **1100** shows the generation segment **102** illustrated in FIG. **2** with a transportation hub **1102** electrically coupled to the power generation equipment **210** of the generation station **202** via a branch line **1120**. Particularly, the branch line **1120** is an electrical connection between the transportation hub and the connector **230**B extending from the power generation equipment **210**. In other examples, the arrangement **1100** may differ in various ways, such as a different position and/or connection of the transportation hub **1102** relative to the generation station **202**. For instance, in another embodiment, the transportation hub **1102** may be electrically coupled to the power generation equipment **210** via another connection (e.g., the connector **230**A) or at a different point on the connector **230**B. Further, in some embodiments, the transportation hub **1102** may be electrically coupled to one or more additional generation stations.

The transportation hub **1102** may be implemented as a facility electrically coupled to receive BTM power from a generation station (e.g., the generation station **202**). As such, the transportation hub **1102** may obtain generated power from the generation station **202** and provide the generated power to electric vehicles via the electric vehicle (EV) charging station **1106**. Particularly, the power interface **1104** of the transportation hub **1102** may obtain power from the power generation equipment via the branch line **1120** and distribute the power to components of the transportation hub via the power bus **1110**. In some instances, the transportation hub **1102** may utilize one or more components to convert power from the generation station **202** into power capable of being supplied to recharging electric vehicles via the EV charging station **1106**. For instance, the transportation hub **1102** may use the energy storage **1108** to store the power obtained from the generation station **202** in preparation for distribution to electric vehicles via the EV charging station **1106**.

In some embodiments, the generation station **202** may be a conventional string of intermittent power generation units ("IPGUS") configured to supply generated power to the electrical grid. As such, the branch line **1120** electrically connecting the transportation hub **1102** to the generation station **202** may be a medium-voltage (e.g., 35 kV) power connector that the transportation hub **1102** to receive power from the generation station **202**.

As shown in FIG. **11**, the transportation hub **1102** may be implemented with a power interface **1104**, an electric vehicle (EV) charging station **1106**, and energy storage **1108**. The transportation hub **1102** may also include one or more components not shown in FIG. **11**, such as a communication interface configured to communicate with one or more external sources (e.g., the remote master control system **300**, the generation station control system **216**). The components within the transportation hub **1102** are shown coupled via the power bus **1110**. In addition, the transportation hub **1102** may be electrically coupled to the generation station **202** via the branch line **1120** as shown. The branch line **1120** may enable the transportation hub **1102** to be located nearby one or more highways or other types of roadways to allow electric vehicles to easily stop and recharge via the EV charging station **1106** of the transportation hub **1102**. In some examples, the transportation hub **1102** may include some physical structure (e.g., a building or overhang cover) to provide shelter to its components and any vehicles using the EV charging station **1106**.

As indicated above, the transportation hub **1102** may be coupled to power generation equipment **210** via one or more branch lines (e.g., branch line **1120**). A branch line may serve as a power connection that can transfer power between two entities, such as from power generation equipment **210** to the power interface **1104** of the transportation hub **1102**.

Within the transportation hub **1102**, the power interface **1104** may serve as an interface between the transportation hub **1102** and the branch line **1120**. The power interface **1104** may be configured to electrically engage or disengage the transportation hub **1102** from the BTM power source (e.g., the generation station **202**). For example, the power interface **1104** may receive an indication to engage or disengage the transportation hub **1102** via a communication interface (not shown) of the transportation hub **1102**. The communication interface may receive the signal to engage or disengage the transportation hub **1102** from one or more external sources (e.g., the remote master control system **300**, the generation station control system **216**). In some instances, the power interface **1104** may engage or disengage the transportation from the generation station **202** rapidly based on intermittent power production by the generation **202** and/or other monitored conditions.

The power interface **1104** may include one or more components capable of receiving power from the power generation equipment **210** and distributing the power to the different components of the transportation hub **1102** via power bus **1110**. This way, the EV charging station **1106** may receive generated BTM power from the generation station **202** via the power interface **1104** and subsequently provide the power to electric vehicles recharging at the transportation hub **1102**. Similarly, the energy storage **1108** may also receive BTM power from the power interface **1104** that originated at the generation station **202** and store the power as energy for later use.

In some embodiments, the power interface **1104** may also be coupled to one or more additional power sources (e.g., another BTM power source, the electric grid). For example, the power interface **1104** may be electrically coupled to one or more additional power sources via one or more additional branch lines. As such, the power interface **1104** may include distribution equipment that enables the transportation hub **1102** to receive power from the different power sources. For instance, the power interface **1104** may selectively switch between the different coupled power sources or may receive power from multiple power sources simultaneously. The size of the transportation hub **1102** as well as the EV charging station **1106** and the energy storage **1108** may depend on the quantity of power sources coupled to the power interface **1104**.

The EV charging station **1106** may represent part of the transportation hub **1102** that includes one or more chargers configured for supplying power to electric vehicles. Each charger may be configured to supply power to one or more electric vehicles at a time. In some examples, the EV charging station **1106** may be configured to supply power obtained from the energy storage **1108** to the recharging electric vehicles. In some instances, the EV charging station **1106** may supply power as the power is received from the generation station **202** via the branch line **1120**.

The energy storage **1108** may represent one or more energy storage systems configured to store power received from the generation station **202** via the power interface **1104**. For instance, the energy storage **1108** may include one or more batteries configured to store BTM power received via the power interface **1104**. The stored power at the energy storage **1108** can be used to supply power to electric vehicles via the EV charging station. In addition, power stored in the energy storage **1108** can be used for other purposes, such as to power lights, equipment, and other components at the transportation hub **1102**. In one embodiment, the energy storage **1108** may include a first unit configured to store power for use by the EV charging station **1106** and a second unit configured to store power for other uses.

FIG. **12** shows a block diagram of a system for modulating power delivery to a transportation hub, according to one or more embodiments. The system **1200** is shown with the remote master control system **300** in wireless communication **1240** with a set of flexible datacenters **1202**, **1206** and a transportation hub **1210**. This arrangement is shown for illustration purposes, but can differ within other examples. In other embodiments, the remote master control system **262** could be implemented as remote master control system **300**, the transportation hub **1102** could be implemented as the transportation hub **1200**, and/or flexible datacenters **220** or **500** could be implemented as flexible datacenters **1202** and/or **1206**. For instance, in another embodiment, the remote master control system **300** may be configured to manage operations at a fleet of datacenters that are positioned at various locations and coupled to different power generation sources.

Within the system **1200**, the remote master control system **300** may be configured to help manage operations at the flexible datacenters **1202**, **1206**, and the transportation hub **1210**. Particularly, the remote master control system **300** may manage computational operations among the flexible datacenters **1202**, **1206**, and operations at the transportation hub **1210**, such as modulating power delivery to the transportation hub **1210**. To perform these management functions, the remote master control system **300** may monitor a set of conditions, such as the availability of BTM power at the flexible datacenters **1202**, **1206**, and/or the transportation hub **1210** and/or a quantity of energy stored at the energy storage **1216** of the transportation hub **1210**. In some situations, changes in the monitored conditions may trigger the remote master control system **300** to adjust operations at the flexible datacenters **1202**, **1206** and/or the transportation hub **1210**.

Although not shown in FIG. **12**, the flexible datacenters **1202**, **1206** and the transportation hub **1210** may be electrically coupled to one or more power generation sources. In one embodiment, the flexible datacenters **1202**, **1206** and the transportation hub **1210** may be electrically coupled to the same BTM power source (e.g., the generation station **202**). As indicated above, the connections may differ because the transportation hub **1210** may be coupled via a branch line (e.g., the branch line **1120** shown in FIG. **11**). In another embodiment, the flexible datacenters **1202**, **1206** and/or the transportation hub **1210** may be electrically coupled to different BTM power sources. For example, the flexible datacenter **1202** and the transportation hub **1210** may be electrically coupled to a first power generation source from which flexible datacenter **1202** and the transportation hub **1210** receive BTM power and the flexible datacenter **1206** may be electrically coupled to a second power generation source from which flexible datacenter **1206** receives BTM power. Other arrangements are possible.

As indicated above, the remote master control system **300** (or another computing system) may manage computational operations among computing systems at the flexible datacenters **1204**, **1206** and operations (e.g., modulate power delivery) at the transportation hub **1210**. Some example monitored conditions may include power availability at each datacenter **1202**, **1206** and/or the transportation hub **1210** (i.e., power availability **1220**) and the price of the different available power options at the datacenters **1202**, **1206** and the transportation hub **1210** (i.e., the power prices **1222**). To illustrate an example situation involving monitored conditions, when the transportation hub **1210** and one or both of the flexible datacenters **1202**, **1206** share a BTM power source, the remote master control system **300** may analyze how to manage use of BTM power (if limited) among the flexible datacenter(s) and the transportation hub **1210** in a way that maximizes profitability using the limited BTM power.

Other monitored conditions may include parameters specifically related to the transportation hub **1210**. For instance, the remote master control system **300** or another computing system may monitor a quantity of energy available in the energy storage **1216**. The amount of stored energy may limit the number of vehicles capable of receiving a recharge from the transportation hub **1210**. Thus, the remote master control system **300** may monitor the energy level of the energy storage **1216** to assist with determining when to modulate power delivery to the transportation hub **1210**.

The remote master control system **300** may also monitor a quantity of vehicles within a threshold distance from the EV charging station **1214**. To monitor the quantity of vehicles, various technologies may be used. In one respect, the transportation hub **1210** may utilize the communication interface **1212** and/or one or more sensors (e.g., cameras, radar) to detect the presence of vehicles nearby the EV charging station **1214**. In another respect, the communication interface **1212** may engage in wireless communication with nearby electric vehicles to determine the quantity of vehicles seeking a recharge at the transportation hub **1212**. In a further aspect, the transportation hub **1210** may utilize a geofence that serve as a virtual geographic boundary defined by GPS or RFID technology around the EV charging station **1214**. As such, the communication interface **1212** may receive a signal for each electric vehicle that enters into the geofence area around the EV charging station.

In addition, the remote master control system **300** or another computing system may monitor weather conditions at datacenters (e.g., the flexible datacenters **1202**, **1206**) and the transportation hub **1210**. The weather conditions may impact operations. For instance, additional power may be required to cool computing systems at one or more datacenters. Weather conditions may also impact the quantity of vehicles recharging at the EV charging station **1214**. The remote master control system **300** or another computing system may similarly monitor weather conditions at one or more power sources supplying generated power to the datacenters and/or the transportation hub **1210**.

The various monitored conditions described above as well as other potential conditions may change dynamically and with great frequency. Thus, to enable efficient management of the flexible datacenters **1202**, **1206** and the transportation hub **1210**, the remote master control system **300** or another computing system may be configured to monitor changes in the various conditions. For instance, the remote master control system **300** may engage in wired or wireless communication **1230** with datacenter control systems (e.g., datacenter control system **504**) at each datacenter, the communication interface **1212** at the transportation hub **1210**, and/or other sources to monitor for changes in the conditions. In turn, the remote master control system **300** may analyze the different conditions in real-time to modulate operating attributes of one or more computing systems at one or more of the datacenters and the transportation hub **1210** (e.g., modulate power delivery to the transportation hub **1210**). By using the monitored conditions, the remote master control system **262** may increase revenue, decrease costs, and/or increase performance of datacenters and the transportation hub **1210** via various modifications, such as transferring computational operations between datacenters or sets of computing systems within a datacenter, adjusting performance at one or more sets of computing systems (e.g., switching to a low power mode), and modifying operations at the transportation hub **1210** (e.g., modulating power delivery to the energy storage **1216**).

When analyzing the monitored conditions, the remote master control system may perform a weighted analysis to manage operations at the datacenters **1202**, **1206**, and the transportation hub **1210**. The weighted analysis may involve assigning weights to each monitored condition such that some of the conditions have more influence on the outcome. In some examples, the weights may be predefined by an administrator or another entity. When a weight is predefined, the remote master control system may use that weight during analysis. Alternatively, some weights may be developed using analysis of the monitored conditions and performance at the datacenters over time.

FIG. **13** illustrates a method for modulating power delivery to a transportation hub, according to one or more embodiments. The method **1300** serves as an example and may include other steps within other embodiments. A datacenter control system (e.g., the remote master control system **262** or **300**) may perform one or more steps of the method **1300**. In some examples, a combination of computing systems may perform one or more steps of the method **1300**.

At step **1302**, the method **1400** involves monitoring a set of conditions. The datacenter control system may monitor one or more conditions, such as BTM power availability at a transportation hub. The transportation hub may be electrically coupled via a branch line to a BTM power source and configured to receive BTM power from the BTM power source. In some instances, the location of the transportation hub may depend on a length of the branch line connecting the transportation hub to the BTM power source. For example, a length of the branch line may position the transportation hub within a threshold distance of the BTM power source (e.g., within 2 miles from the BTM power source).

In some embodiments, the transportation hub may be implemented as a facility with an EV charging station, energy storage, a communication interface, and a power interface that can engage or disengage the transportation hub from the BTM power source. For instance, the transportation hub may be implemented as the transportation hub **1102** shown in FIG. **11** or the transportation hub **1210** shown in FIG. **12**. The energy storage system may include one or more batteries for storing power received from the BTM power source.

In one respect, the BTM power source may include a generation station configured to generate utility-scale electrical power for supply to an electrical grid. In another respect, the transportation hub may be electrically connected to a generation station at a location behind a Point of Interconnection between the generation station and an electrical grid. In another respect, the BTM power received by the transportation hub may be electrical power produced by a generation station and transmitted to the transportation hub behind the generation station's Point of Interconnection with an electrical grid.

In another respect, the transportation hub may be electrically connected to a generation station that is subject to metering by one or more utility-scale generation-side meter that measure power supplied from the generation station to an electrical grid. For instance, the BTM power received by the transportation hub may not have passed through the one or more utility-scale generation-side meters. In another respect, the power received by the transportation hub may be received from a generation station that is subject to metering by one or more utility-scale generation-side meters. The BTM power received by the transportation hub may not be metered by the one or more utility-scale generation-side meters.

In another respect, the transportation hub is electrically connected to a generation station that supplies utility-scale power to a grid. Power received from the grid is subject to Transmission and/or Distribution charges, but the BTM power received by the transportation hub from the generation station may not be subject to Transmission and/or Distribution charges.

The set of conditions may vary within embodiments. Some example monitored conditions may include BTM power availability at the transportation hub, a quantity of energy stored at the energy storage of the transportation hub, and/or a quantity of electric vehicles seeking a recharge at the EV charging station of the transportation hub. For instance, the remote master control system or another computing system (e.g., a system at the transportation hub) may monitor the a quantity of vehicles within a threshold distance of the transportation hub using sensors, a geofence positioned around the transportation hub, wireless communication and/or other technologies. In addition, weather conditions at the transportation hub, datacenters, and/or generation stations may also be monitored.

At step **1304**, the method **1400** involves modulating power delivery to the transportation hub based on the set of monitored conditions. Particularly, the datacenter control system may modulate power based on one or more of the monitored conditions. In some examples, the datacenter control system may modulate power to the transportation hub to maximize profitability or for other reasons (e.g., maximize vehicles receiving charge from the charging station).

In some examples, the datacenter control system may monitor the quantity of energy stored in the energy storage. In some instances, the datacenter control system may determine that the quantity of energy stored in the energy storage is below a threshold quantity and also determine that BTM power is available for delivery to the transportation hub. The datacenter control system may modulate power delivery to the transportation hub based on these conditions. For instance, the datacenter control system may cause the power interface to electrically engage the transportation hub to the BTM power source to enable power delivery to the energy storage based on determining that the quantity of energy stored in the energy storage is below the threshold quantity and determining that BTM power is available for delivery to the transportation hub.

In some examples, the datacenter control system may determine that the quantity of energy stored in the energy storage is above a threshold quantity. As a result, the datacenter control system may cause the power interface to electrically disengage the transportation hub from the BTM power source to disable power delivery to the energy storage based on determining that the quantity of energy stored in the energy storage is above the threshold quantity.

In some examples, the datacenter control system may determine that BTM power is not available for delivery to the transportation hub. As a result, the datacenter control system may causing the power interface to electrically disengage the transportation hub from the BTM power source to disable power delivery to the energy storage based on determining that the BTM power is not available for delivery to the transportation hub.

In some examples, an additional transportation hub may be electrically coupled to the BTM power source. Similar to the other transportation hub, the additional transportation hub receives behind-the-meter ("BTM") power from the BTM power source. For instance, the additional transportation hub may be electrically coupled to the BTM power source via the same branch line as the other transportation hub. In other instances, the additional transportation hub may utilize its own branch line to obtain power from the BTM power source. As such, the datacenter control system may modulate power delivery to the transportation hubs based on monitored conditions, which may include a comparison of available energy stored at the transportation hub versus available energy stored at the second transportation hub.

Advantages of one or more embodiments of the present invention may include one or more of the following:

One or more embodiments of the present invention provides a green solution to two prominent problems: the exponential increase in power required for growing blockchain operations and the unutilized and typically wasted energy generated from renewable energy sources.

One or more embodiments of the present invention allows for the rapid deployment of mobile datacenters to local stations. The mobile datacenters may be deployed on site, near the source of power generation, and receive low cost or unutilized power behind-the-meter when it is available.

One or more embodiments of the present invention provide the use of a queue system to organize computational operations and enable efficient distribution of the computational operations across multiple datacenters.

One or more embodiments of the present invention enable datacenters to access and obtain computational operations organized by a queue system.

One or more embodiments of the present invention allows for the power delivery to the datacenter to be modulated based on conditions or an operational directive received from the local station or the grid operator.

One or more embodiments of the present invention may dynamically adjust power consumption by ramping-up, ramping-down, or adjusting the power consumption of one or more computing systems within the flexible datacenter.

One or more embodiments of the present invention may be powered by behind-the-meter power that is free from transmission and distribution costs. As such, the flexible datacenter may perform computational operations, such as distributed computing processes, with little to no energy cost.

One or more embodiments of the present invention provides a number of benefits to the hosting local station. The local station may use the flexible datacenter to adjust a load, provide a power factor correction, to offload power, or operate in a manner that invokes a production tax credit and/or generates incremental revenue.

One or more embodiments of the present invention allows for continued shunting of behind-the-meter power into a storage solution when a flexible datacenter cannot fully utilize excess generated behind-the-meter power.

One or more embodiments of the present invention allows for continued use of stored behind-the-meter power when a flexible datacenter can be operational but there is not an excess of generated behind-the-meter power.

One or more embodiments of the present invention allows for management and distribution of computational operations at computing systems across a fleet of datacenters such that the performance of the computational operations take advantages of increased efficiency and decreased costs.

One or more embodiments of the present invention allows for management and modulation of power delivery at a transportation hub configured with energy storage and an electric vehicle charging station.

It will also be recognized by the skilled worker that, in addition to improved efficiencies in controlling power delivery from intermittent generation sources, such as wind farms and solar panel arrays, to regulated power grids, the invention provides more economically efficient control and stability of such power grids in the implementation of the technical features as set forth herein.

While the present invention has been described with respect to the above-noted embodiments, those skilled in the art, having the benefit of this disclosure, will recognize that other embodiments may be devised that are within the scope of the invention as disclosed herein. Accordingly, the scope of the invention should be limited only by the appended claims.

What is claimed is:

1. A system comprising:

a transportation hub electrically coupled to a BTM power source via a branch line, wherein the transportation hub includes an electrical vehicle charging station and an energy storage system, wherein the energy storage system includes one or more batteries that are configured to obtain and store behind-the-meter ("BTM") power from the BTM power source; and

a datacenter control system configured to modulate power delivery to the transportation hub based on a set of monitored conditions, wherein the set of monitored conditions includes BTM power availability at the transportation hub, a quantity of energy stored at the energy storage system, and a quantity of vehicles located within a threshold distance from the electrical vehicle charging station.

2. The system of claim **1**, wherein the BTM power source comprises a generation station configured to generate utility-scale electrical power for supply to an electrical grid.

3. The system of claim **1**, wherein the transportation hub is electrically connected to a generation station at a location behind a Point of Interconnection between the generation station and an electrical grid.

4. The system of claim **1**, wherein the BTM power received by the transportation hub is electrical power produced by a generation station and transmitted to the transportation hub behind the generation station's Point of Interconnection with an electrical grid.

5. The system of claim **1**, wherein the transportation hub is electrically connected to a generation station that is subject to metering by one or more utility-scale generation-side meter that measure power supplied from the generation station to an electrical grid, and

wherein the BTM power received by the transportation hub has not passed through the one or more utility-scale generation-side meters.

6. The system of claim **1**, wherein the power received by the transportation hub is received from a generation station that is subject to metering by one or more utility-scale generation-side meters, and

wherein the BTM power received by the transportation hub is not metered by the one or more utility-scale generation-side meters.

7. The system of claim **1**, wherein the transportation hub is electrically connected to a generation station that supplies utility-scale power to a grid,

wherein power received from the grid is subject to Transmission and/or Distribution charges, and

wherein the BTM power received by the transportation hub from the generation station is not subject to Transmission and/or Distribution charges.

8. The system of claim **1**, wherein the set of monitored conditions further comprises:

a first price associated with supplying BTM power to the transportation hub versus a second price associated with supplying power to an electrical grid.

9. The system of claim **1**, wherein the datacenter control system is a remote master control system positioned remotely from the transportation hub, and

wherein the remote master control system communicates with a communication interface of the transportation hub.

10. The system of claim **9**, wherein the transportation hub further comprises:

a power interface configured to electrically engage or disengage the transportation hub from the BTM power source,

wherein the power interface electrically engages or disengages the transportation hub from the BTM power source based on instructions from the remote master control system.

11. The system of claim **1**, wherein a length of the branch line positions the transportation hub within a threshold distance of the BTM power source.

12. The system of claim **1**, further comprising:

a second transportation hub electrically coupled to the BTM power source, wherein the second transportation hub receives behind-the-meter ("BTM") power from the BTM power source.

13. The system of claim **12**, wherein the second transportation hub is electrically coupled to the BTM power source via the branch line.

14. The system of claim **12**, wherein the datacenter control system is further configured to modulate power delivery to the transportation hub and the second transportation hub based on the set of monitored conditions, and

wherein the set of monitored conditions includes a comparison of available energy stored at the transportation hub versus available energy stored at the second transportation hub.

15. A method comprising:

monitoring, by a datacenter control system, a set of conditions, wherein the set of conditions includes behind-the-meter ("BTM") power availability at a transportation hub, a quantity of energy stored at an energy system located at the transportation hub, and a quantity of vehicles located within a threshold distance from an electrical vehicle charging station located at the transportation hub, and wherein the transportation hub is electrically coupled to a BTM power source via a branchline such that one or more batteries associated with the electrical vehicle charging station are configured to obtain and store BTM power from the BTM power source; and

modulating, by the datacenter control system, power delivery to the transportation hub based on the set of monitored conditions.

16. The method of claim **15**, wherein the BTM power source comprises a generation station configured to generate utility-scale electrical power for supply to an electrical grid.

17. The method of claim **15**, wherein the transportation hub is electrically connected to a generation station at a location behind a Point of Interconnection between the generation station and an electrical grid.

18. The method of claim **15**, wherein the BTM power received by the transportation hub is electrical power produced by a generation station and transmitted to the transportation hub behind the generation station's Point of Interconnection with an electrical grid.

19. The method of claim **15**, wherein the transportation hub is electrically connected to a generation station that is subject to metering by one or more utility-scale generation-side meter that measure power supplied from the generation station to an electrical grid, wherein the BTM power received by the transportation hub has not passed through the one or more utility-scale generation-side meters.

20. The method of claim **15**, wherein power received by the transportation hub is received from a generation station that is subject to metering by one or more utility-scale generation-side meters, and wherein the BTM power received by the transportation hub is not metered by the one or more utility-scale generation-side meters.

21. The method of claim **15**, wherein the transportation hub is electrically connected to a generation station that supplies utility-scale power to a grid,

wherein power received from the grid is subject to Transmission and/or Distribution charges, and

wherein the BTM power received by the transportation hub from the generation station is not subject to Transmission and/or Distribution charges.

22. The method of claim **15**, wherein the transportation hub comprises:

an electrical vehicle charging station;

a power interface configured to electrically engage or disengage the transportation hub from the BTM power source; and

an energy storage having one or more batteries; and

wherein monitoring the set of conditions comprises:

monitoring a quantity of energy stored in the energy storage.

23. The method of claim **22**, wherein monitoring the quantity of energy stored in the energy storage comprises:

determining that the quantity of energy stored in the energy storage is below a threshold quantity;

determining that BTM power is available for delivery to the transportation hub; and

wherein modulating, by the datacenter control system, power delivery to the transportation hub based on the set of monitored conditions comprises:

causing the power interface to electrically engage the transportation hub to the BTM power source to enable power delivery to the energy storage based on determining that the quantity of energy stored in the energy storage is below the threshold quantity and determining that BTM power is available for delivery to the transportation hub.

24. The method of claim **22**, wherein monitoring the quantity of energy stored in the energy storage comprises:

determining that the quantity of energy stored in the energy storage is above a threshold quantity; and

wherein modulating, by the datacenter control system, power delivery to the transportation hub based on the set of monitored conditions comprises:

causing the power interface to electrically disengage the transportation hub from the BTM power source to disable power delivery to the energy storage based on determining that the quantity of energy stored in the energy storage is above the threshold quantity.

25. The method of claim **22**, wherein monitoring the quantity of energy stored in the energy storage comprises:

determining that BTM power is not available for delivery to the transportation hub; and

wherein modulating, by the datacenter control system, power delivery to the transportation hub based on the set of monitored conditions comprises:

causing the power interface to electrically disengage the transportation hub from the BTM power source to disable power delivery to the energy storage based on determining that the BTM power is not available for delivery to the transportation hub.

26. A non-transitory computer-readable medium configured to store instructions, that when executed by a computing system, causes the computing system to perform functions comprising:

monitoring a set of conditions, wherein the set of conditions includes behind-the-meter ("BTM") power availability at a transportation hub, a quantity of energy stored at an energy system located at the transportation hub, and a quantity of vehicles located within a threshold distance from an electrical vehicle charging station located at the transportation hub, and wherein the transportation hub is electrically coupled to a BTM power source via a branchline such that one or more batteries associated with the electrical vehicle charging station are configured to obtain and store BTM power from the BTM power source; and

modulating power delivery to the transportation hub based on the set of monitored conditions.

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